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LAKE VICTORIA

STATE OF THE BASIN REPORT *2025*

JUMUIYA YA AFRIKA MASHARIKI

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The **Lake Victoria Basin Commission** (LVBC) is a specialized institution of the East African Community mandated to coordinate sustainable development and management of the Lake Victoria Basin. Headquartered in Kisumu, Kenya, LVBC serves as the regional platform for cooperation among Partner States, providing policy guidance, technical coordination, and harmonized frameworks to safeguard the basin's natural resources while promoting socio-economic transformation, environmental sustainability, and regional integration.

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LAKE VICTORIA

STATE OF THE BASIN
REPORT 2025

Water Quality in Decline: Can Lake Victoria Recover?

March 2026

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The LVBC also expresses its deep appreciation to the Secretariat staff for their dedicated leadership and technical oversight throughout the preparation of the SoBR. The Secretariat provided strategic guidance to the consultants, ensured alignment with regional policy and institutional frameworks, and played a central role in coordinating inputs across Partner States. Through careful review of draft outputs and the provision of timely, constructive feedback, the Secretariat contributed significantly to improving the quality, coherence, and relevance of the final report.

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Quick facts on Lake Victoria Basin

FEATURE	VALUE
Physical Geography & Hydrology	
Lake Victoria surface area	68,800 km² (world's second largest lake by surface area)
Total Lake Victoria Basin area	259,800 km²
Terrestrial catchment area	193,000 km²
Mean lake volume	2,424 km³
Mean lake depth	~40 m
Maximum lake depth	80–84 m
Lake elevation	~1,134 m above mean sea level
Length of shoreline	~3,440 km
Mean annual precipitation	~1,273 mm (2000–2022)
Net Basin Supply	~20–30 BCM per year
Total water withdrawals	~2,408 MCM per year
Location & Basin Structure	
Geographic location	1°18' N to 4°06' S; 29°30' E to 35°10' E
Number of sub-basins	23 sub-catchments
Highest point in basin	Wagagai, Mt. Elgon – 4,321 m
Main inflowing rivers	Kagera, Nzoia, Gucha–Migori, Sondu-Miriu, Simiyu, Mara, Yala, Nyando, Isanga, Biharamulo
Sole outflowing river	Victoria Nile
Countries & Population	
Riparian countries	Burundi, Kenya, Rwanda, Tanzania, Uganda
Share of terrestrial catchment	Tanzania 44%; Kenya 22%; Uganda 16%; Rwanda 11%; Burundi 7%
Share of lake surface	Tanzania 51%; Uganda 43%; Kenya 6%
Population within basin	>45 million people
Average population density	~350 persons/km²
Economy, Livelihoods & Infrastructure	
Contribution of LVB to regional GDP	~60 %
Annual fish catches	~1.14 million tonnes
Annual beach value of fisheries	~US$1.12 billion
Main commercial fish species	Nile perch, Nile tilapia, Dagaa
Major towns in the basin	Kampala, Entebbe, Jinja, Mbarara, Masaka, Kisumu, Kisii, Kitale, Mwanza, Musoma, Bukoba, Kigali
Main lake ports	Kisumu, Mwanza, Port Bell; others include Musoma, Jinja, Port Victoria, Kemondo Bay, Bukoba, Nugwe, Muhuru Bay




JEHOVA JIRE

Foreword



Hon. Beatrice Askul Moe

Chairperson, Sectoral Council of Ministers for Lake Victoria Basin (SECOM)

Cabinet Secretary, Ministry of East African Community, The ASALs, and Regional Development Republic of Kenya

The Lake Victoria Basin is the heart of the East African Community—a shared ecological asset and a powerful engine for the social and economic advancement of our people. Its waters and resources transcend our borders, binding our Partner States in a common destiny and underscoring the fundamental principles of our integration agenda. Yet this vital resource faces escalating pressures from climate change, population growth, and environmental degradation. These are not national issues but regional challenges that demand a unified and decisive response.

Thus, it is with great pride and responsibility that I present this inaugural State of the Lake Victoria Basin Report (SoBR). For the first time, we have a comprehensive, evidence-based baseline of the basin's condition—consolidated data that equips us for sound policymaking, harmonized policies, and strategic investments to ensure a sustainable development trajectory.

The report demonstrates how sustainable management of the basin can drive inclusive growth and transformation. By unlocking opportunities in food and water security, renewable energy, climate resilience, tourism, and the blue economy, the basin can be a source of peace, prosperity, and stability for our region.

On behalf of the Sectoral Council of Ministers for Lake Victoria Basin, I congratulate the Lake Victoria Basin Commission and all partners who contributed to this groundbreaking achievement.

The collaborative process that produced this report is itself a testament to the spirit of regional cooperation.

I call upon my fellow policymakers, our esteemed development partners, the scientific community, and civil society to use this report as a guide to action. Let us commit to safeguarding the Lake Victoria Basin for today's citizens and as a lasting legacy of peace, resilience, and prosperity for generations to come.

> By unlocking opportunities in food and water security, renewable energy, climate resilience, tourism, and the blue economy, the basin can be a source of peace, prosperity, and stability for our region.



Preface



Dr. Masinde Bwire

Executive Secretary, Lake Victoria Basin Commission (LVBC) Secretariat

It is my pleasure to present the inaugural State of the Lake Victoria Basin Report (SoBR), a milestone for the East African Community. This report fulfills a long-held ambition to replace fragmented information with a single, authoritative baseline on the condition of our most vital shared resource. In direct fulfillment of the Lake Victoria Basin Commission's (LVBC) mandate, this report moves us from assumption to evidence, establishing a definitive scientific benchmark—covering biophysical, social, economic, and governance aspects—against which future progress can be measured.

The development of this report was a rigorous and highly consultative undertaking, anchored by a multi-disciplinary team of technical experts from our Partner States to ensure regional ownership. The process involved extensive data collection, synthesis workshops, and a thorough peer-review by independent experts to guarantee scientific credibility.

This landmark achievement would not have been possible without the contributions of many. We extend our sincere gratitude to the EAC Sectoral Council of Ministers for Lake Victoria Basin for their invaluable policy guidance. We thank the Governments of the Republics of Burundi, Kenya, Rwanda, Uganda, and the United Republic of Tanzania for providing their experts and national data. We gratefully acknowledge the crucial technical and financial support from our development partners, particularly the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Finally, our profound appreciation goes to the lead authors, peer reviewers, and the LVBC Secretariat staff for their intellectual rigor and tireless coordination.

This inaugural report is the first step in institutionalizing a long-term monitoring framework. It is our firm conviction that this commitment to evidence-based management is the most effective path toward our shared vision of a prosperous and sustainable Lake Victoria Basin.

> "The development of this report was a rigorous and highly consultative undertaking, anchored by a multi-disciplinary team of technical experts from our Partner States to ensure regional ownership."


Telkom
Rwakou Kisumu Dala
BUY A

HOW TO USE THIS REPORT

The State of the Basin Report (SoBR) 2025 is not designed to be read like a novel—from cover to cover—but rather as a comprehensive reference tool and a decision-support system Whether you are developing a national water plan, preparing an investment proposal, conducting environmental assessments, or tracking progress toward development goals, this report provides the evidence base you need to make informed decisions about the Lake Victoria Basin's sustainable future.

A Guide for Policymakers, Planners, and Practitioners

Who Should Use This Report and How

For Policymakers and Strategic Planners

1. Read the Key Messages at the beginning of each chapter for immediate takeaways.
2. Read Chapter 9 (Synthesis, Outlook, and the Future of the Basin) for integrated findings, scenarios, and strategic recommendations
3. Then consult: Chapter 8 (Water Governance) to understand institutional frameworks and coordination mechanisms
4. Use the indicators at the beginning of each chapter to track progress toward SDGs, Agenda 2063, and the LVBC IWRMD Strategy
5. Application: Informing policy reforms, updating Nationally Determined Contributions (NDCs), and aligning national strategies with regional commitments

For Researchers and Scholars

- **Treat as:** An authoritative synthesis of basin-wide data and peer-reviewed literature
- **Refer to:** The Indicator Report (standalone technical document) for detailed methodologies, data sources, and analytical approaches
- **Use for:** Identifying research gaps, baseline data for studies, comparative analyses, and understanding long-term environmental trends. Pay attention to the "Data Gaps" highlighted in technical chapters to guide future research priorities.
- **Application:** Academic research, postgraduate studies, and contributing to the evolving knowledge base

Navigation by Structure

The report follows a logical flow from context to action. If you want to understand

- **The Context:** The physical geography, demographics, and history of the basin; go to: Part I (Chapters 1–2).
- **The Health:** The physical condition of the lake, rivers, biodiversity, and water quality; go to: Part II (Chapters 3–5).
- **The Pressures:** How human economies (fisheries, agriculture, energy) and climate change are impacting the basin; go to Part III (Chapters 6–7).
- **The Response:** How we are governing the basin and what future scenarios look like; go to: Part IV (Chapters 8–9).

For Investment and Project Planners

- **Start with:** Chapter 2 (Basin Overview) for context, then navigate to relevant sectoral chapters (Chapters 3-7)
- **Hotspots:** Identify priority geographic areas, sectors, and pressures requiring intervention (e.g., pollution hotspots in Chapter 5 or water-stressed zones in Chapter 6).
- **Assess** whether existing management responses are delivering results
- **Ground investment** decisions in a credible, basin-wide evidence base.
- **Application:** Designing bankable projects, prioritizing investments in high-impact areas, and ensuring interventions address root causes

Water and environmental management practitioners

Will find value in:

- The detailed assessments in Chapters 3–7 on ecosystems, water resources, water quality, sectoral water use, and climate change
- The analysis of drivers, trends, and spatial patterns of change; and
- The identification of monitoring gaps and capacity needs relevant to implementation.
- Application: Operational planning, monitoring and evaluation, adaptive management, and transboundary coordination.

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List of **Acronyms**

ACC-LVB	Adapting to Climate Change in the Lake Victoria Basin (Project)
ADCP	Acoustic Doppler Current Profiler
AF	Adaptation Fund
AfCFTA	African Continental Free Trade Area
AfDB	African Development Bank
AFOLU	Agriculture, Forestry, and Other Land Use
ASCENT	Accelerating Sustainable Control and Elimination of Neglected Tropical Diseases (Program)
ASM	Artisanal and Small-Scale Mining
AU-PIDA	African Union Programme for Infrastructure Development in Africa
AfDB	African Development Bank
Agenda 2063	The Africa We Want (African Union development framework)
ASALs	Arid and Semi-Arid Lands
AWS	Automatic Weather Stations
BAU	Business as Usual
BCM	Billion Cubic Meters
BGR	Federal Institute for Geosciences and Natural Resources (Germany)
BMU	Beach Management Unit
BMZ	Federal Ministry for Economic Cooperation and Development (Germany)
BOD	Biochemical Oxygen Demand
BMUs	Beach Management Units
BMZ	Federal Ministry for Economic Cooperation and Development (Germany)
C3A2	Community Climate Change Adaptation Assessment
CAB	Congo Air Boundary
CAS	Catchment Assessment Survey (Regional Catch Assessment Surveys)
CBD	Convention on Biological Diversity
CBT	Community-Based Tourism
CCA	Climate Change Adaptation
CADRI	Capacity for Disaster Reduction Initiative
CCTTFA	Central Corridor Transit Transport Facilitation Agency
COMESA	Common Market for Eastern and Southern Africa
DRBC	Delaware River Basin Commission
EAC	East African Community
EACOP	East African Crude Oil Pipeline
EAPP	East African Power Pool
EALA	East African Legislative Assembly
ERA	Electricity Regulatory Authority
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Development Agency)
GDP	Gross Domestic Product
GWP	Global Water Partnership
HDI	Human Development Index
HVDC	High-Voltage Direct Current
ICT	Information and Communications Technology
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
IWRMD	Integrated Water Resources Management and Development
kV	Kilovolt
LVB	Lake Victoria Basin
LVBC	Lake Victoria Basin Commission
MW	Megawatt
NAPs	National Adaptation Plans
NBI	Nile Basin Initiative
NCTTCA	Northern Corridor Transit and Transport Coordination Authority
NDCs	Nationally Determined Contributions
OSBP/OSBPs	One-Stop Border Post(s)
PIDA	Programme for Infrastructure Development in Africa
PSR	Pressure-State-Response (assessment framework)
SDGs	Sustainable Development Goals
SECOM	Sectoral Council of Ministers for Lake Victoria Basin
SGR	Standard-Gauge Railway
SoBR	State of the Basin Report
TPDC	Tanzania Petroleum Development Corporation
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNOC	Uganda National Oil Company
USD	United States Dollar
WWA	Western Water Assessment
WWF	World Wide Fund for Nature
CCCF	County Climate Change Fund (Kenya)
CFA	Cooperative Framework Agreement
CICOS	International Commission of the Congo-Oubangui-Sangha Basin
CIFOR-ICRAF	Centre for International Forestry Research–World Agroforestry
CLTS	Community-Led Total Sanitation
CMIP	Coupled Model Intercomparison Project
COD	Chemical Oxygen Demand
CPAR	Country Poverty Assessment Report
CRESTI-LVB	Climate Resilience for Sustainable Maritime Transport Infrastructure in Lake Victoria Basin
CREWS	Climate Risk and Early Warning Systems
CSA	Climate-Smart Agriculture
DMI	Domestic, Municipal, and Industrial
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DPSIR	Drivers-Pressures-State-Impact-Response
DRC	Democratic Republic of Congo
DRR	Disaster Risk Reduction
DTR	Diurnal Temperature Range
EAC	East African Community

EAPP	Eastern Africa Power Pool
EbA	Ecosystem Based Adaptation
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EICV	Integrated Household Living Conditions Survey (Rwanda)
ENSO	El Niño-Southern Oscillation
EU	European Union
FAO	Food and Agriculture Organization
FDC	Flow Duration Curve
FEOW	Freshwater Ecoregions of the World
FONERWA	Rwanda's Green Fund
FSM	Fecal Sludge Management
GBON	Global Basic Observing Network
GCF	Green Climate Fund
GCM	Global Climate Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GEMS	Global Environment Monitoring System
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiance
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWh	Gigawatt hours
HABs	Harmful Algal Blooms
HIGHWAY	High Impact Weather Lake System (Project)
IGAD	Intergovernmental Authority on Development
IGEBU	Institut Géographique du Burundi
IHO	International Hydrographic Organization
ILK	Indigenous and Local Knowledge
ILO	International Labour Organization
IOD	Indian Ocean Dipole
IOM	International Organization for Migration
IPBES	Intergovernmental Science-Policy Platform on Biodiversity & Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IRB	Independent Regulatory Board
ISO	International Organization for Standardization
ISTEEBU	Institut de Statistiques et d'Études Économiques du Burundi
ITCZ	Intertropical Convergence Zone
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported and Unregulated (fishing)
IWRM	Integrated Water Resources Management
IWRMD	Integrated Water Resources Management and Development
IWT	Inland Water Transport
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme (WHO/ UNICEF)
KACP	Kenya Agricultural Carbon Project
KCCA	Kampala Capital City Authority
KeFS	Kenya Fisheries Service
KES	Kenya Shillings
KfW	Kreditanstalt für Wiederaufbau (German Development Bank)
KIWASCO	Kisumu Water and Sanitation Company
KMFRI	Kenya Marine and Fisheries Research Institute
KNBS	Kenya National Bureau of Statistics
KV	Kilovolt
LDMS	Laboratory Data Management Systems
LEDS	Low Emission Development Strategies
LST	Lake Surface Temperature
LST	Local Standard Time
LULC	Land Use and Land Cover
LULCC	Land Use and Land Cover Change
LVB	Lake Victoria Basin
LVBC	Lake Victoria Basin Commission
LVB-WIS	Lake Victoria Basin Water Information System
LVEMP	Lake Victoria Environmental Management Project
LVFO	Lake Victoria Fisheries Organization
LVWATSAN	Lake Victoria Water and Sanitation Initiative
LWIS	Lakewide Inclusive Sanitation
MACS	Migration and Climate-informed Solutions
MAM	March-April-May (Long Rains)
masl	Meters Above Sea Level
MCM	Million Cubic Meters
MCS	Monitoring, Control and Surveillance
MDG	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
MGR	Metre Gauge Railway
MLVMCT	Multinational Lake Victoria Maritime Communications and Transport
MoE	Ministry of Environment (Rwanda)
MoFPED	Ministry of Finance, Planning and Economic Development (Uganda)
MOH	Ministry of Health
MOW	Ministry of Water (Tanzania)
MPI	Multidimensional Poverty Index
MRCC	Maritime Rescue Coordination Centre
MRV	Monitoring, Reporting, and Verification
MT	Metric Tonnes
MW	Megawatt
MWE	Ministry of Water and Environment (Uganda)
NaFIRRI	National Fisheries Resources Research Institute
NAP	National Adaptation Plan
NASA	National Aeronautics and Space Administration
NBA	Niger Basin Authority
NB-DSS	Nile Basin Decision Support System
NBI	Nile Basin Initiative
NBS	National Bureau of Statistics (Tanzania)
NBS	Net Basin Supply
NbS	Nature-Based Solutions
NCCR	Nile Cooperation for Climate Resilience
NDC	Nationally Determined Contributions

ND-GAIN	Notre Dame Global Adaptation Initiative
NEL	Nile Equatorial Lakes
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NEMA	National Environment Management Authority (Kenya/Uganda)
NEMC	National Environment Management Council (Tanzania)
NGO	Non-Governmental Organization
NIA	National Irrigation Authority (Kenya)
NIB	National Irrigation Board (Kenya)
Nile DEWS	Nile Drought Early Warning System
NISR	National Institute of Statistics of Rwanda
NLC	National Land Commission
NPV	Net Present Value
NRW	Non-Revenue Water
NSS	Non-Sewered Sanitation
NTU	Nephelometric Turbidity Units
NWMP	National Water Master Plan
NWSC	National Water and Sewerage Corporation (Uganda)
O&M	Operation and Maintenance
OCGS	Office of the Chief Government Statistician
OND	October-November-December (Short rains/ Transition)
OPHI	Oxford Poverty & Human Development Initiative
ORASECOM	Orange-Senqu River Commission
PAYG	Pay-As-You-Go
PES	Payment for Ecosystem Services
PET	Potential Evapotranspiration
PFAS	Per- and Polyfluoroalkyl Substances
PHL	Post-Harvest Losses
POP	Persistent Organic Pollutant
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PPP	Purchasing Power Parity
PSR	Pressure–State–Response (assessment framework)
QA/QC	Quality Assurance/Quality Control
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
REMA	Rwanda Environment Management Authority
RH	Relative Humidity
Ro-Pax	Roll-on/Roll-off Passenger
Ro-Ro	Roll-on/Roll-off
RV	Research Vessel
RVS	Regional Vision Scenario
RWB	Rwanda Water Resources Board
SALM	Sustainable Agricultural Land Management
SAPP	Southern African Power Pool
SAR	Search and Rescue
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
SEFA	Sustainable Energy Fund for Africa
SEZ	Special Economic Zone
SGR	Standard Gauge Railway
SHS	Solar Home Systems
SME	Small and Medium Enterprise
SMM	Sio-Malaba-Malakisi
SoBR	State of the Basin Report
SON	September-October-November (Short Rains)
SSP	Shared Socioeconomic Pathway
TAFIRI	Tanzania Fisheries Research Institute
TBA	Transboundary Aquifer
TDS	Total Dissolved Solids
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
UBOS	Uganda Bureau of Statistics
UKCEH	UK Centre for Ecology & Hydrology
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UN-Habitat	United Nations Human Settlements Programme
UNICEF	United Nations Children's Fund
UNWTO	United Nations World Tourism Organization
US$, USD	United States Dollar
UTIP	Uganda-Tanzania Interconnection Project
VAT	Value Added Tax
WAP	Water Allocation Plan
WASAC	Water and Sanitation Corporation (Rwanda)
WASH	Water, Sanitation and Hygiene
WASREB	Water Services Regulatory Board (Kenya)
WEIS	Water and Environment Information System (Uganda)
WHO	World Health Organization
WIS	Water Information System
WMO	World Meteorological Organization
WQI	Water Quality Index
WRA	Water Resources Authority (Kenya)
WRUA	Water Resource User Association
WSN	Wireless Sensor Networks
WTP	Willingness to Pay
WWTP	Wastewater Treatment Plant
ZAMCOM	Zambezi Watercourse Commission

SECTION I →
Setting the Scene



Chapter 1

INTRODUCTION

1.1. The concept of a State of the Basin report

The State of the Basin Report (SoBR), which is a flagship publication that provides a comprehensive assessment of the ecological, social, and economic conditions within a river or lake basin, is a globally recognized tool for implementing Integrated Water Resources Management (IWRM) (MRC, 2018; GWP, 2015). Its fundamental purpose is to assemble, synthesize, and interpret existing information from various sources to create a holistic, evidence-based picture of the basin's health, the pressures upon it, and the effectiveness of current management responses (WWF, 2022).

Based on the dominant narrative and evidence emerging across the technical chapters of this report, water quality clearly stands out as the most critical and systemic risk to the Lake Victoria Basin. Degradation driven by terrestrial watershed pressures, sediment and nutrient loading, organic pollution, eutrophication, toxic algal blooms, hypolimnetic anoxia, bioaccumulation of heavy metals, and associated public health impacts threatens the lake's ecological integrity, economic productivity, and human well-being. In recognition of both the scale of this challenge and its basin-wide implications, the Partner States deliberately framed this inaugural report around water quality. Accordingly, the full title of the report is ***State of the Basin Report 2025: Water Quality in Decline—Can Lake Victoria Recover?***, signaling both the gravity of current trends and the urgency of coordinated action to reverse them.

Beyond diagnosis, the SoBR's critical role is to build an improved understanding of basin-wide issues and opportunities, thereby enabling informed water resources management and long-term planning, especially in transboundary contexts where multiple jurisdictions must coordinate actions (MRC, 2018; UNECE, 2023). By aligning diverse data into a common framework, the SoBR equips decision-makers with the knowledge needed to prioritize interventions, balance competing sectoral demands, and design strategies that optimize shared benefits across political boundaries (World Bank, 2022a,). Using agreed indicators, it tracks whether basin health is improving or declining, guiding resource allocation toward persistent challenges and emerging threats (WWF, 2022; DRBC, 2019).

The value of a SoBR extends far beyond the document itself; it is an instrument for adaptive governance. Prepared at regular intervals, as in the Nile and Mekong basins, it links evaluation of existing strategies to the formulation of new ones, embedding accountability and adaptive management into basin governance (MRC, 2018).

In transboundary contexts, the SoBR creates a "shared understanding" among diverse decision-makers. By synthesizing data from different national jurisdictions into a single, coherent narrative, the SoBR provides an agreed-upon factual foundation for dialogue, negotiation, and collaborative action (Western Water Assessment, 2020; Delaware River Basin Commission, 2019).

The process of preparation of a SoBR is as important as the final product. The act of bringing together scientists, technical experts, and policymakers from different countries to agree on data, indicators, and interpretations is a powerful exercise in building trust and strengthening institutional relationships. This collaborative process creates a basin-wide community of practice committed to a shared vision for sustainable development of the basin.

Furthermore, the SoBR serves as a vital instrument of performance management and accountability for the basin organization itself. River basin organizations risk losing legitimacy if they cannot show tangible outcomes. For institutions like the Lake Victoria Basin Commission (LVBC), the SoBR demonstrates effectiveness to governments and partners, justifying continued investment in cooperation (WWF, 2022). In this way, the report is both a scientific reference and a governance tool for sustaining regional cooperation.

1.2. Rationale and justification for the SoBR

The Lake Victoria Basin is a lifeline for over 45 million people across Burundi, Kenya, Rwanda, Tanzania, and Uganda, supporting fisheries, water supply, hydropower, transport, and climate regulation (World Bank, 2022; Awange, 2021; LVBC, 2007). Its inland fishery alone generates over USD 1 billion annually and employs more than three million people (Awange, 2021). Yet this immense natural capital faces mounting, interconnected pressures that place the basin at a tipping point.

Key drivers of degradation include rapid population growth and urbanization that overwhelm sanitation systems (World Bank, 2022, 2025; LVBC, 2024), catchment deforestation and erosion that load sediment and pollutants into the lake (World Bank, 2008, 2023; Juma et al., 2014), and severe nutrient-driven eutrophication, which has multiplied algal biomass fivefold since the 1960s and created extensive anoxic "dead zones" (Awange, 2021; Van der Knaap et al., 2004; Juma et al., 2014). Climate change magnifies these risks, bringing more frequent floods and droughts, hydropower instability, and climate migration projected to displace up to 38.5 million people by 2050 (IPCC, 2014, 2021; World Bank, 2021).

The ecological decline in the lake basin directly threatens regional economies—through declining fisheries, rising water treatment costs, damage to hydropower, and losses in tourism (World Bank, 2008, 2023; Awange, 2021). Against this backdrop, the inaugural SoBR is not just an environmental assessment but a risk management tool, reframing stewardship of Lake Victoria as essential to sustainable development, poverty reduction, and long-term stability.

1.3. Process for Preparation of the SoBR

1.3.1. General approach

The credibility and utility of this ***State of the Basin Report*** rest on the integrity of the process through which it was developed. Recognizing that the management of a shared resource requires shared ownership of the evidence, the preparation of this report was guided by core principles of collaboration, scientific rigor, and transparency. This methodology was designed not only to produce a high-quality technical document but also to strengthen the institutional fabric of transboundary cooperation within the Lake Victoria Basin.

The development process was fundamentally stakeholder-driven, premised on the understanding that sustainable management can only be achieved with the active involvement of those whose livelihoods and well-being depend on the basin's resources (Reed et al., 2015).

1.3.2. Technical Process and Methodology

The preparation of the SoBR followed a ten-step methodology designed to ensure scientific rigor, stakeholder ownership, and policy relevance (Figure 1-1). The process moved from data synthesis to indicator development, validation, and finally the production of the report itself.

1. **Process concept development and validation:** This stage focused on defining the overall SoBR approach, scope, and structure, followed by presentation to and validation by the Partner States. It established agreement on the report's objectives, thematic focus, and expected outputs, ensuring collective ownership from the outset.

2. **Indicator development:** Building on the validated concept, LVBC reviewed national, regional, and international datasets to develop a harmonized set of Pressure–State–Response (PSR) indicators aligned with the SDGs, Agenda 2063, and regional strategies. The process emphasized data comparability, long-term trends, and cross-country consistency, with indicators embedded in chapter narratives using the DPSIR framework.
3. **Validation and gap-filling:** The proposed indicators were reviewed with Partner States, and supplementary data were collected to address identified gaps.
4. **Finalization:** Indicators and datasets were standardized, quality-checked, and compiled into an Indicator Report—the technical backbone of the SoBR.
5. **Launching the Indicator Report:** The report was produced as a standalone technical document providing detailed analyses of indicators, trends, data sources, and methodologies. It serves both as a foundational component of the SoBR and as an independent reference tool for policymakers and technical experts.
6. **Storyline development:** Indicator findings were transformed into thematic narratives explaining the relationships among pressures, states, and societal responses.
7. **Drafting and key messages:** Technical results were synthesized into policy-relevant messages and integrated into the first full draft of the SoBR.
8. **Validation workshops:** Drafts and key messages were reviewed through basin-wide consultations to ensure technical soundness and regional consensus.
9. **Incorporation of feedback:** National perspectives and stakeholder inputs were integrated into the revised draft, ens**uring alignment with Partner State priorities.**
10. **Finalization:** The process concluded with the production of a consensus-based SoBR—combining scientific robustness, stakeholder legitimacy, and policy relevance.

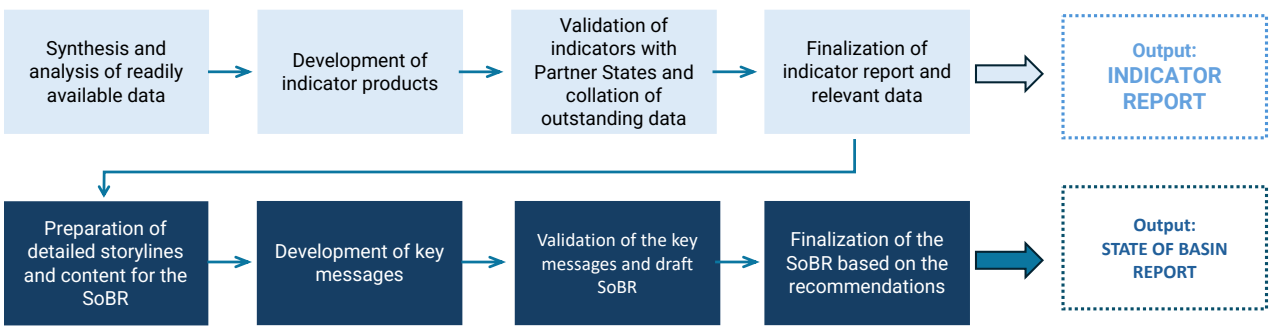


Figure 1-1. *Methodology for the development of the SoBR*

1.3.3. Basin State Indicators

A central component of the *State of the Basin Report* (SoBR) preparation process was the **collaborative development and selection of a core set of indicators** capturing the state of natural resources, the pressures driving their degradation, and the societal responses addressing these challenges. These indicators form the analytical backbone of the report, providing a coherent framework for assessing the health and sustainability of the Lake Victoria Basin.

At the beginning of each technical chapter is a table of indicators relevant to the theme of the chapter. But rather than just presenting the indicators as a matrix of statistics, they are fully integrated into the **narrative of each chapter**, where they are contextualized through graphs,

tables, and interpretive analysis. This approach ensures that data are not viewed merely as numbers, but as evidence underpinning the story of the basin's environmental, social, and economic trajectory.

The indicators establish a clear and credible **baseline for future State of the Basin reporting** cycles. This will allow the Lake Victoria Basin Commission and Partner States to track long-term trends, assess management effectiveness, and measure progress toward shared goals. Importantly, these indicators are aligned with **regional, continental, and global frameworks**—including the EAC Vision 2050, the *African Union's Agenda 2063,* and the *Sustainable Development Goals (SDGs)*—creating a transparent and objective basis for evaluating outcomes and strengthening institutional accountability for sustainable basin management (WWF, 2022).

1.3.4. Stakeholder engagement

Stakeholder engagement was structured at multiple levels to ensure that the report reflects both national priorities and a coherent regional perspective. This involved:

- **National Consultations:** Targeted engagements with key ministries (e.g., Water, Environment, Agriculture, Fisheries), national technical agencies (e.g., environmental management authorities, meteorological services, fisheries research institutes), and civil society platforms in each of the five Partner States.
- **Regional Technical Workshops:** Thematic workshops brought together experts from across the basin to review data, discuss trends, and deliberate on the key messages for specific chapters.
- **High-Level Validation:** The final draft of the report was subjected to a comprehensive regional validation workshop, providing Partner States and key regional stakeholders with a final opportunity to review the findings, contribute to the recommendations, and formally endorse the report, ensuring its collective ownership and political legitimacy



Figure 1-2. *Participants at the Regional Validation Workshop for the SoBR – January 2026, Nairobi, Kenya.*

1.3.5 Data as Diplomacy: The Unifying Process of the SoBR

The technical foundation of the State of Basin Report (SoBR) is built on the best available scientific data and information. In recognition of the fact that limited access to, and harmonization of, national data systems remains one of the most persistent challenges in transboundary water cooperation (UNECE, 2023), a concerted effort was made to establish a coherent and defensible regional evidence base. This process involved systematic data requests to national institutions, extensive use of peer-reviewed scientific literature, and the incorporation of analyses from flagship reports produced by UN agencies and international organizations, including the World Bank.

In total, 417 key data points were identified as necessary for the preparation of the first edition of the SoBR. These data requirements spanned two broad categories: basin-wide state descriptors characterizing the overall condition and functioning of the Lake Victoria Basin, and country-specific state descriptors reflecting sectoral conditions within national portions of the basin.

As shown in Table 1-1, data coverage at the whole-of-basin level is relatively strong, with over three-quarters of the required state descriptors available, providing a solid foundation for basin-wide assessments. In contrast, data availability at the country level varies markedly among Partner States. Kenya and Tanzania show comparatively high coverage, broadly consistent with the basin average, while Uganda exhibits moderate gaps. More pronounced data limitations are evident for Rwanda and Burundi, where less than one-third of the required state descriptors were available. These disparities reflect differences in national monitoring capacity, data management systems, and historical investment in sectoral information, and they highlight the need for targeted investments in data generation, harmonization, and sharing to support more balanced and comprehensive basin-wide reporting. The next cycle of the State of Basin Report needs to put greater emphasis on collection of country-specific data.

Table 1-1: Data availability for preparation of the State of Basin Report (SoBR)

Data Category	Data Availability 2025 (%)
Whole-of-basin state descriptors	75.5
Country-specific state descriptors	
Tanzania	76.8
Kenya	76.8
Uganda	41.0
Rwanda	29.9
Burundi	25.6

In a transboundary context, the seemingly technical tasks of data sharing, agreeing on common indicators, and validating information through stakeholder consultation constitute powerful acts of water diplomacy that require overcoming national sensitivities and building mutual trust. By leading and facilitating the complex process of development of the SoBR, the Lake Victoria Basin Commission has not only coordinated the production of a report but has strengthened its mandate as the central platform for regional cooperation, dialogue, and confidence-building. The SoBR thus transcends its technical function: it stands as tangible proof of the Partner States' unity of purpose and their commitment to safeguarding the basin as a shared natural heritage.

1.4. Strategic Alignment: From Basin Priorities to Global Commitments

The State of the Basin Report (SoBR) is a practical tool for policy implementation, monitoring, and strategic alignment. It anchors its findings and recommendations within the existing regional, continental, and global commitments of the Lake Victoria Basin Partner States, providing the evidence base needed to measure progress, identify gaps, and accelerate collective action toward shared sustainability goals.

1.4.1 Regional frameworks

At the regional level, the *State of the Basin Report* (SoBR) serves as the principal monitoring and evaluation tool for three strategic frameworks shaping the basin's future:

- **EAC Vision 2050:** This overarching vision seeks to transform the region into a prosperous, competitive, and secure upper-middle-income bloc (EAC, 2016). A key pillar is the sustainable use of natural resources with enhanced value addition. The SoBR provides a vital reality check, assessing the condition of the natural resource base that underpins this ambition and highlighting where environmental degradation threatens long-term productivity and prosperity.
- **LVBC Integrated Water Resources Management and Development Strategy (2023–2050):** The basin's foundational management blueprint. The SoBR supplies the baseline data and trend analyses needed to track progress toward the strategy's five goals on ecosystem restoration, pollution control, water development, climate resilience, and governance (LVBC, 2024).
- **LVBC Strategic Plan (2021–2026):** The plan defines the Commission's institutional priorities and operational focus areas (LVBC, 2021). The SoBR provides the evidence base for identifying emerging challenges and opportunities, which in turn inform updates of the Strategic Plan and subsequent management cycles. This creates a continuous feedback loop between basin assessment, strategic planning, and implementation—illustrated schematically in Figure 1-3. Through this alignment, the SoBR ensures that LVBC's institutional planning and resource allocation remain grounded in the most current and comprehensive basin data.

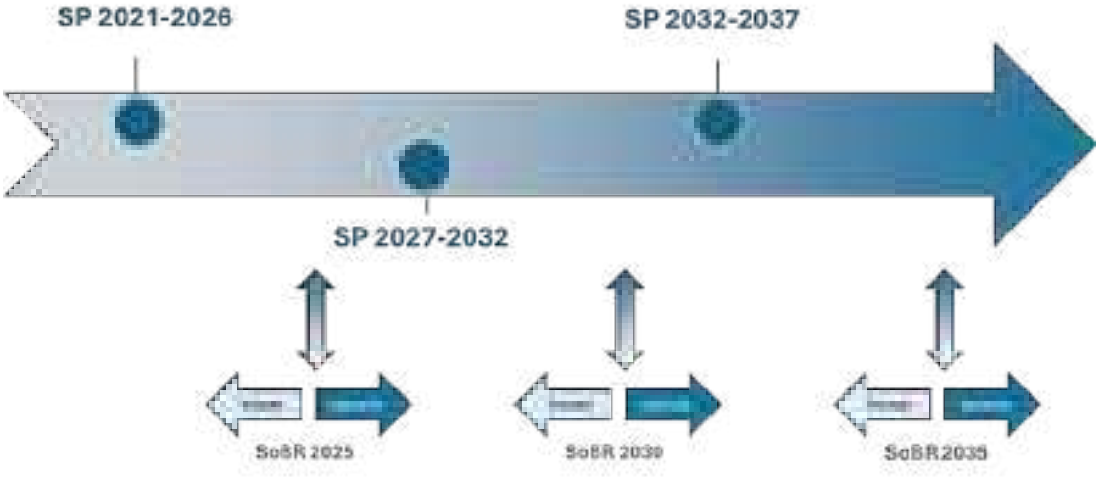


Figure 1-3. *The LVBC Strategic Planning Cycle*

1.4.2 Continental Frameworks

At the continental level, the *State of the Basin Report* (SoBR) aligns with the African Union's Agenda 2063: *The Africa We Want* (AUC, 2015). It provides a concrete diagnosis of the challenges and opportunities in achieving **Aspiration 1**—"A prosperous Africa based on inclusive growth and sustainable development"—and its related goals on environmentally sustainable and climate-resilient economies. The sustainable management of the Lake Victoria Basin is therefore a vital contribution to realizing this continental vision.

1.4.3 Global Frameworks

At the global level, the SoBR supports Partner States in tracking and reporting on major international commitments:

- **2030 Agenda for Sustainable Development (SDGs):** The SoBR is a key tool for monitoring progress on **SDG 6 (Clean Water and Sanitation)**—especially Targets 6.3, 6.5.1, and 6.5.2 (UN-Water, 2023)—and contributes data relevant to SDGs 13, 14, 15, and 2.
- **UNFCCC and Paris Agreement:** By assessing basin-wide climate impacts, vulnerabilities, and adaptation responses, the report provides essential inputs for updating **Nationally Determined Contributions (NDCs)** and **National Adaptation Plans (NAPs).**

By making trade-offs between economic growth, ecosystem health, and climate resilience explicit, the SoBR promotes a more integrated, nexus-based policy dialogue—supporting the transition toward a greener and more resilient development pathway for the Lake Victoria Basin.

1.5 Structure of the Report

The State of the Basin Report (SoBR) is organized into four interlinked parts that follow the **Pressure–State–Response (PSR)** logic, guiding the reader from context and diagnosis to governance and strategic outlook.

Part I: Setting the Scene introduces the basin.

- **Chapter 1** presents the background and methodology.
- **Chapter 2** provides an overview of the basin's geography, ecosystems, demographics, and development challenges.

Part II: The State of Natural Resources analyzes the condition of the basin's core natural assets.

- **Chapter 3:** Ecosystems and biodiversity.
- **Chapter 4:** Water resources quantity and hydrology.
- **Chapter 5:** Water quality and pollution sources.

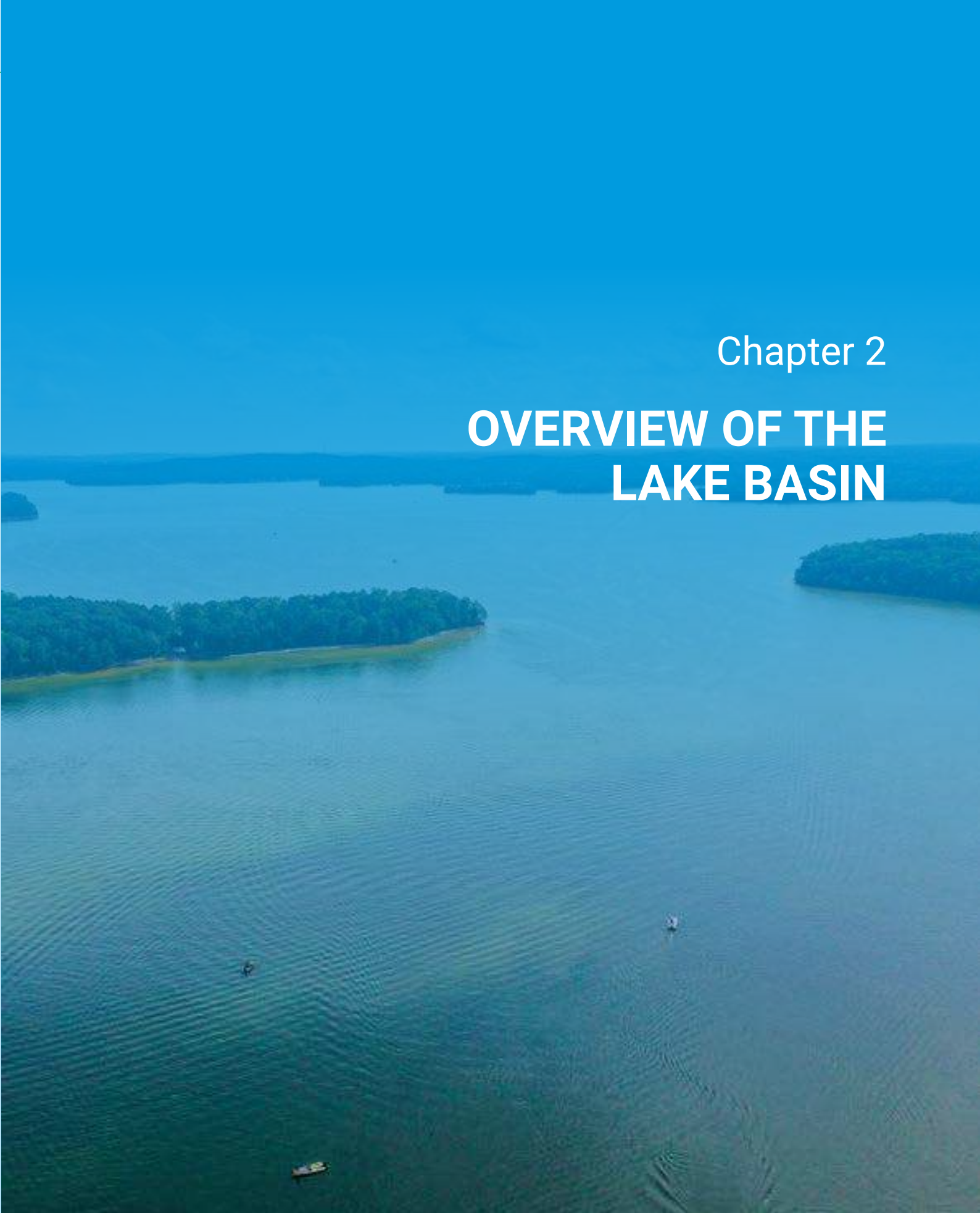
Part III: Water Use, Development, and a Changing Climate examines water use across key sectors and the effects of climate change.

- **Chapter 6:** Sectoral water demand and economic use.
- **Chapter 7:** Climate change, vulnerability, and resilience.

Part IV: Governance, Synthesis, and Strategic Outlook integrates findings and sets the way forward.

- **Chapter 8:** Water governance and institutional frameworks.
- **Chapter 9:** Synthesis, scenarios, and strategic recommendations.

This structure embodies the IWRM philosophy—moving logically from understanding basin conditions to identifying collective responses for sustainable management.



Chapter 2

OVERVIEW OF THE LAKE BASIN

SUMMARY CHAPTER 2

Chapter 2 establishes the biophysical and socio-economic foundations of the Lake Victoria Basin (LVB). Its purpose is to provide a holistic picture of the basin's geography, climate, ecosystems, demographics, and economy, highlighting the drivers of both opportunity and vulnerability. By synthesizing this context, the chapter frames the challenges and choices that will shape the basin's future development and sustainability.



Geography & Hydrology

The basin covers 241,520 km², with 68,800 km² of lake surface, shared by Tanzania (51%), Uganda (43%), and Kenya (6).



Economy & Livelihoods

Agriculture remains the backbone, employing >70% of the population.

Lake Victoria supports ~1 million metric tons/year with landed value ~USD 600 million, employing over 3 million people.



Demography

The basin hosts 45+ million people (2025 est.),, growing at 3.5–3.8% annually, faster than national averages. Population is projected to reach 113–165 million by 2050.

Geography and Hydrology

- The Lake Victoria Basin spans ~259,800 km² (68,800 km² of lake surface) shared by Tanzania (51 %), Uganda (43 %), and Kenya (6 %), draining parts of Rwanda and Burundi.
- As a shallow tropical lake (mean depth ~40 m; maximum depth of 80-84 m), Lake Victoria is highly sensitive to climatic variation; ~80 % of its inflow derives from direct rainfall and only ~20 % from rivers, making its level a strong indicator of regional hydro-climatic balance.
- The basin's hydrology is dominated by rainfall–evaporation exchanges and regulated outflows at Jinja.
- Its ecosystems—forests, wetlands, and savannas—support exceptional biodiversity but face severe pressure from deforestation, pollution, and invasive species.

Demography and Human Settlements

- The basin hosts over 45 million people (2025 est.), growing at 3.5–3.8 % annually—among the fastest in Africa. Population could reach 113–165 million by 2050.
- Average density (~350 persons/km²) rises above 1,500 persons/km² in lakeshore and highland zones, intensifying competition for land, water, and services.
- The population is overwhelmingly young (65–74 % under 25 years), implying both high dependency and potential for a demographic dividend.
- Urbanization is accelerating around Kampala, Kisumu, Mwanza, and Kigali, yet most growth is unplanned, expanding informal settlements and pollution hotspots.
- Migration—driven by economic integration

and climate stress—is reshaping settlement patterns; by 2050, up to 38 million people in basin countries could be displaced internally by climate-related water and food stress.

Economy and Livelihoods

- Agriculture remains the mainstay, employing over 70 % of residents and contributing about 30 % to national GDPs, but shrinking farm sizes and declining soil fertility constrain productivity.
- The Lake Victoria fishery (~1 million tons per year, ~USD 1.1 billion value) sustains > 3 million people but is threatened by overfishing, eutrophication, and habitat loss.
- The basin underpins East Africa's energy and trade systems: hydropower from the Victoria Nile provides most of Uganda's electricity; major transport corridors and ports connect the region's economies; and digital networks and ICT services are rapidly expanding though still unequal.
- Overall, the basin contributes nearly 60 % of the combined GDP of EAC Partner States—making it the region's economic engine and a key focus for sustainable growth.

Infrastructure and Regional Integration

- Regional integration is advancing through multimodal transport corridors, cross-border energy interconnectors (e.g., Rusumo Falls, Ethiopia–Kenya HVDC link), and digital-market harmonization under EAC and LVBC coordination.
- Despite progress, infrastructure gaps, weak maintenance, and climate vulnerability constrain competitiveness; sustainable, climate-resilient, and inclusive investment remains essential.

Key State Indicators – Socio-Economic Dimension (2025)

Strategic & Thematic Areas	Indicator / Metric	Value / Range (2025)
S.1 Demographics and socio-economic profile		
S1.1 Demographic profile	Basin population	~45 million
	Average population density	~350 persons/km²
	Population density (highlands & cities)	>1,500 persons/km²
	Annual population growth rate	3.5–3.8 % per year
	Urbanisation rate	4–6 % per year
S1.2 Standard of living	Access to basic drinking water services	62–82 %
	Access to basic sanitation facilities	24–74 %
	Access to basic hygiene services	6–52 %
	Access to electricity	11–75 %
	Population below international poverty line	46–74 %
	Population below national poverty line	16.1–39.8 %
S.2 Economic activity and livelihoods		
S2.1 Economic sectors, activities and livelihoods	Combined GDP of Partner States	US$171 billion
	LVB contribution to combined GDP	~60 %
	GDP – Agriculture	21–30 %
	GDP – Industry and manufacturing	9–36 %
	GDP – Services	29–56 %
	Employment – Agriculture	32–85 %
	Employment – Industry and manufacturing	7–17 %
	Employment – Services	29–52 %
	Informal employment share	83–98 %
S2.2 Food production	Crop gross food production index	100–150
	Livestock gross food production index	88–145
	Total food gross production index	110–135
S2.3 Tourism	Contribution to regional GDP	~10 %
	Contribution to export earnings	~17 %
	Contribution to regional employment	~7 %
	Tourist arrivals (LVB Partner States)	~10 million per year

2.1 Geography and Physiography

This section provides a foundational overview of the Lake Victoria Basin (LVB). It defines the basin's geographic extent and describes its intricate topography and hydrology, and the fundamental geological, climatic, and ecological characteristics that govern its natural systems and shape its human use. This analysis sets the stage for subsequent chapters that will explore the basin's socio-economic dynamics, environmental pressures, and management challenges.

2.1.1 Geographic and Political Profile

The Lake Victoria Basin, covering about 259,800 km², dominates the East African landscape and forms the headwaters of the White Nile (Sutcliffe & Parks, 1999). Lying astride the equator between 0.55° N–3.05° S and 31.5°–34.9° E, the lake itself spans roughly 68,800 km², making it the world's largest tropical lake and the second-largest freshwater lake by surface area after Lake Superior.

The basin's drainage area (terrestrial catchment) of 193,000 km² extends across five EAC Partner States: Tanzania (44 %), Kenya (22 %), Uganda (16 %), Rwanda (11 %), and Burundi (7 %) (UNEP, 2006). The lake surface is shared by three riparian nations—Tanzania (51 %), Uganda (43 %), and Kenya (6 %). Hydrologically, the basin is subdivided into 23 sub-basins that together sustain its ecological and economic diversity.

2.1.2 Topography, Elevation, and Major Physical Features

The basin lies within a broad, shallow depression on the East African Plateau, framed by the Albertine and Gregory Rift escarpments. Elevations range from Mount Elgon (4,321 m) to the lake surface at 1,134 m asl. Steep highlands such as the Mau Forest Complex and Nandi Escarpment in Kenya give way to gently sloping plains, including the Kano Plains and the Kagera Delta.

Despite its vast area, Lake Victoria is shallow—averaging 40 m and reaching a maximum of about 80–84 m, with an estimated total volume of 2,424 km³ (Hamilton et al., 2022). Although it ranks as the world's second-largest freshwater lake by surface area, its relatively shallow depth makes it modest in volume compared to deeper lakes such as Tanganyika and Malawi. Its 3,440-km shoreline is highly indented, forming bays and gulfs such as Winam, Speke, and Emin Pasha, and hosting numerous islands, including Ukerewe (Tanzania) and the Ssese Archipelago (Uganda). These features are illustrated in Figure 2-1.

“Lying astride the equator between 0.55° N–3.05° S and 31.5°–34.9° E, the lake itself spans roughly 68,800 km², making it the world's largest tropical lake and the second-largest freshwater lake by surface area after Lake Superior.”

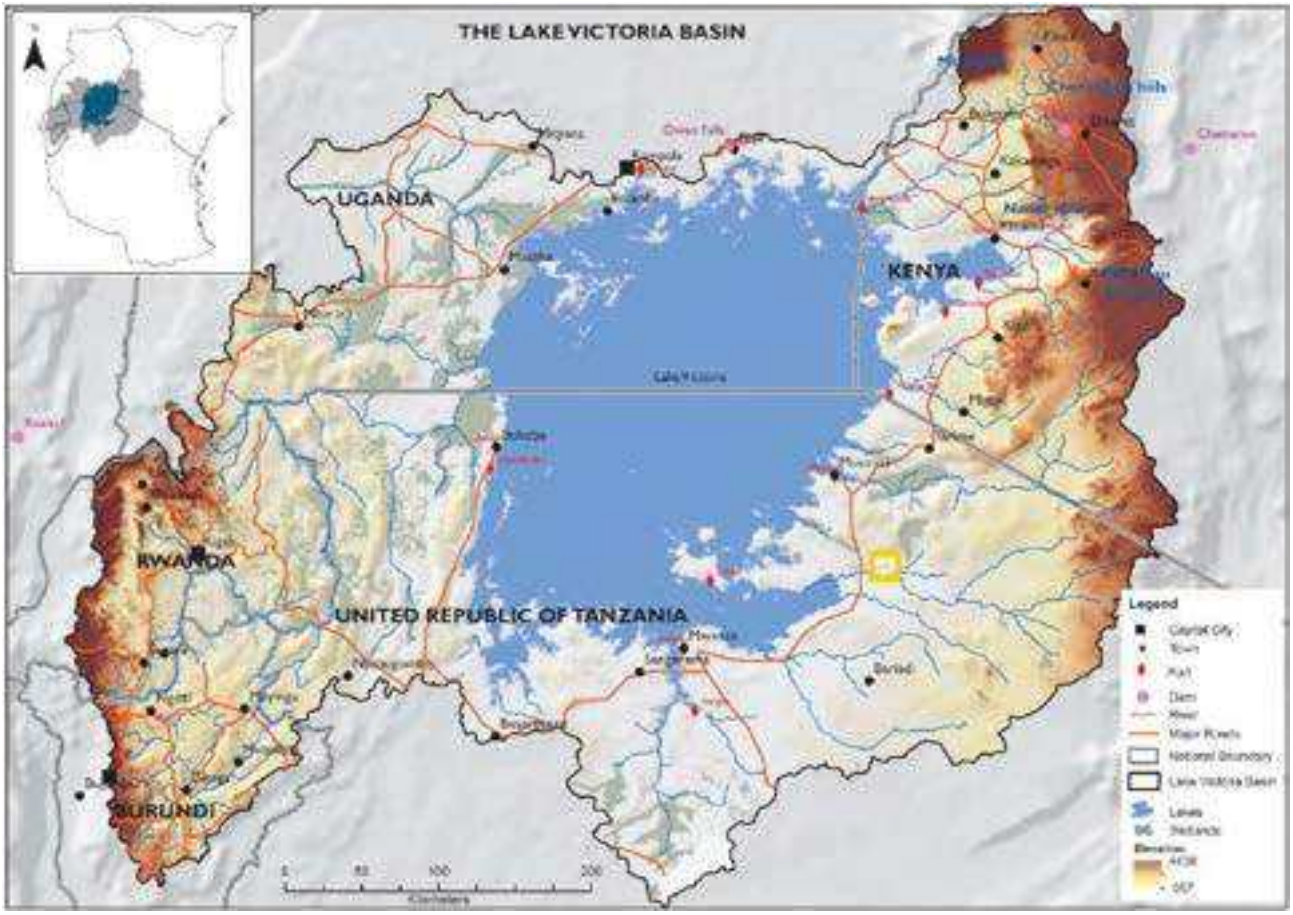


Figure 2-1. *Map showing Physical features _ Source is SRTM, NASA and NBI- NTEAP, 2009*

2.1.3 Climate Patterns and Trends

2.1.3.1 A Complex and Dynamic Climate System

The Lake Victoria Basin (LVB) experiences a highly dynamic climate shaped by the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) and strong local influences from the lake itself. The ITCZ's passage produces a bimodal rainfall pattern—the long rains (March–May) and the short rains (October–December) (Hao et al., 2022).

Lake Victoria's vast surface modulates this pattern by generating powerful land–lake breezes. Daytime heating suppresses convection, while nighttime cooling drives convergence and intense early-morning thunderstorms, accounting for most of the rainfall directly over the lake (Anyah & Semazzi, 2004; Awange, 2021).

Annual rainfall ranges from about 1,200 to over 2,000 mm, with mean maximum temperatures between 24°C and 29°C (UNEP, 2016).

The basin's climate is sensitive to **large-scale oscillations**, especially the **El Niño–Southern Oscillation (ENSO)**, which amplifies short-rain events and flood risk during El Niño years (Onyutha et al., 2016). These interactions make the basin a unique climatic "crucible," where **global signals are reshaped by local geography,** complicating predictions and intensifying climate variability.

2.1.3.2 Anthropogenic Pressures and Environmental Change

Rapid population growth and land-use change have profoundly altered the basin's hydrology. Since the 1920s, the population has grown more than six-fold, driving deforestation, wetland

loss, and urban expansion (Nyeko-Ogiramoi et al., 2013). These transformations reduce infiltration and groundwater recharge, while expanding impervious surfaces increases surface runoff and river "flashiness."

Consequently, the basin's capacity to store and slowly release water—the natural hydrological buffer—has been greatly reduced. Under such conditions, even meteorologically normal dry spells now more readily escalate into severe agricultural or hydrological droughts, as soil moisture depletes faster and baseflows decline more rapidly than under natural land cover. These human-induced changes have therefore lowered the basin's resilience to the growing volatility of its climate (Nyeko-Ogiramoi et al., 2013).

2.1.3.3 Emerging Climate Trends

Recent decades show clear warming—up to 0.7 °C between 1971 and 2000—and increasing rainfall variability (Luhunga et al., 2020). The long rains are weakening and often delayed, while the short rains are intensifying (Evans et al., 2020). This shift contributes to the so-called "East Africa Climate Change Paradox," where overall rainfall may rise but occurs in shorter, more extreme bursts (Adams et al., 2023). These conditions have led to more frequent floods and droughts, exemplified by the record-high lake levels of 2019–2020, linked to anthropogenic climate change (Pietroiusti et al., 2023). More detailed discussion of the basin's climate appears in Chapter 7.

2.1.4 Hydrology and Water Balance

The Lake Victoria Basin (LVB) supports a dense network of rivers and wetlands whose hydrology is shaped by the region's bi-modal rainfall regime, driven by the seasonal migration of the Inter-Tropical Convergence Zone. Most rivers display a twin-peak hydrograph, with high flows during the long rains (March–May) and short rains (October–December), and a pronounced low-flow period between June and September (Kizza et al., 2009; Nyadawa & Mwangi, 2010).

Hydrologically, the basin includes both flashy and attenuated river systems. Rivers such as the Nzoia, Nyando, Yala, Sondu-Miriu in Kenya and the Mara and Simiyu in Tanzania respond rapidly to rainfall, producing sharp flood peaks and heavy sediment loads due to steep slopes, vegetation loss, and reduced floodplain storage (Li et al., 2009; Okungu et al., 2014; Wabusya et al., 2015). In contrast, the Kagera River, draining about 60,000 km² across four countries, has a highly attenuated flow regime, with extensive lakes and papyrus wetlands that moderate floods and sustain stable baseflows year-round (Sutcliffe & Parks, 1999). Wetlands such as the Yala Swamp provide similar localized buffering and sediment-trapping functions, improving the quality of inflows to the lake (Luyiga et al., 2015; Gikuma-Njuru et al., 2018).

At the lake scale, the water balance is dominated by atmospheric exchanges rather than riverine inflows. Direct precipitation over the lake contributes about 80–82 % of total inflows, while evaporation—approximately twice the rate over the surrounding land—accounts for nearly the same proportion of outflows (Sene & Plinston, 1994; Sutcliffe, 2009). River inflows supply the remaining ~20 %, with the Victoria Nile serving as the sole outlet at Jinja, Uganda, where flows have been regulated since the 1950s by the Nalubaale and Kiira dams (Vanderkelen et al., 2018). Because inflows and losses are largely atmospheric, lake-level variations primarily reflect regional climatic fluctuations rather than changes in catchment runoff (Tate et al., 2004).

2.1.5 Geology and Soils

The Lake Victoria Basin (LVB) is a geologically young feature, formed about 400,000 years ago through tectonic movements associated with the East African Rift System. Upwarping of the rift shoulders dammed ancient westward-flowing rivers, creating the broad, shallow depression on the Tanzania Craton that later filled to form the present lake (Beadle, 1981; Johnson et al., 2000). Geological evidence indicates that the lake has undergone several wet–dry cycles and has completely dried up at least three times in its history (Johnson et al., 2000). The overall geological structure is illustrated in Figure 2-2.

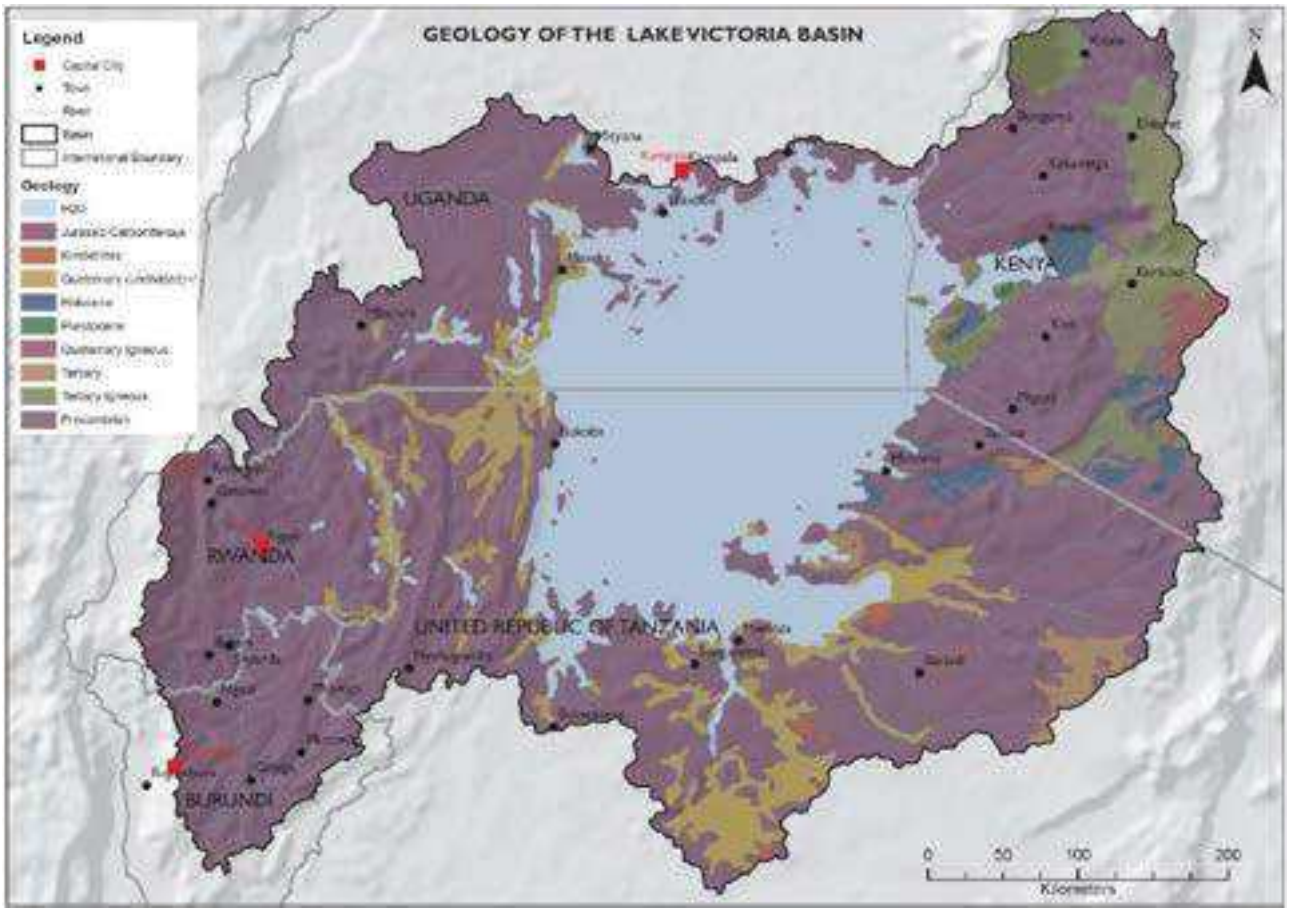


Figure 2-2. *Geology of the Lake Victoria Basin (source: United States Geological Survey, 2002, Surficial geology of Africa (geo7_2ag) (Short form is "U.S. Geological Survey (USGS)")*

The basin is underlain mainly by Precambrian granites, gneisses, and schists of Archean and Proterozoic age (Mulumba, 2004). Tertiary rifting along the Nandi–Elgeyo–Mau escarpments triggered extensive alkaline volcanism, forming basalts, trachytes, and phonolites around the Tinderet–Kericho–Kisumu area and large basaltic sequences on Mt. Elgon (Williams & Macdonald, 1986). Overlying these basement rocks are widespread Quaternary alluvial and lacustrine deposits—clays, silts, and sands—formed in valleys, deltas, and floodplains. These unconsolidated sediments, together with lateritic and volcaniclastic materials, dominate the low-lying landscapes and deltas feeding the lake. The region also contains mineralized greenstone belts, such as the Lake Victoria Goldfields in Tanzania, which host major gold deposits (Kabete et al., 2012).

The basin's soils are products of prolonged tropical weathering of these ancient formations (Figure 2-3). The uplands are dominated by Ferralsols and Lixisols—deep, fine-textured, but nutrient-poor soils with low cation exchange capacity and high susceptibility to compaction (Fungo et al., 2011). In contrast, Gleysols prevail in low-lying floodplains and wetlands, where poor drainage causes seasonal or permanent waterlogging (Mulumba, 2004).

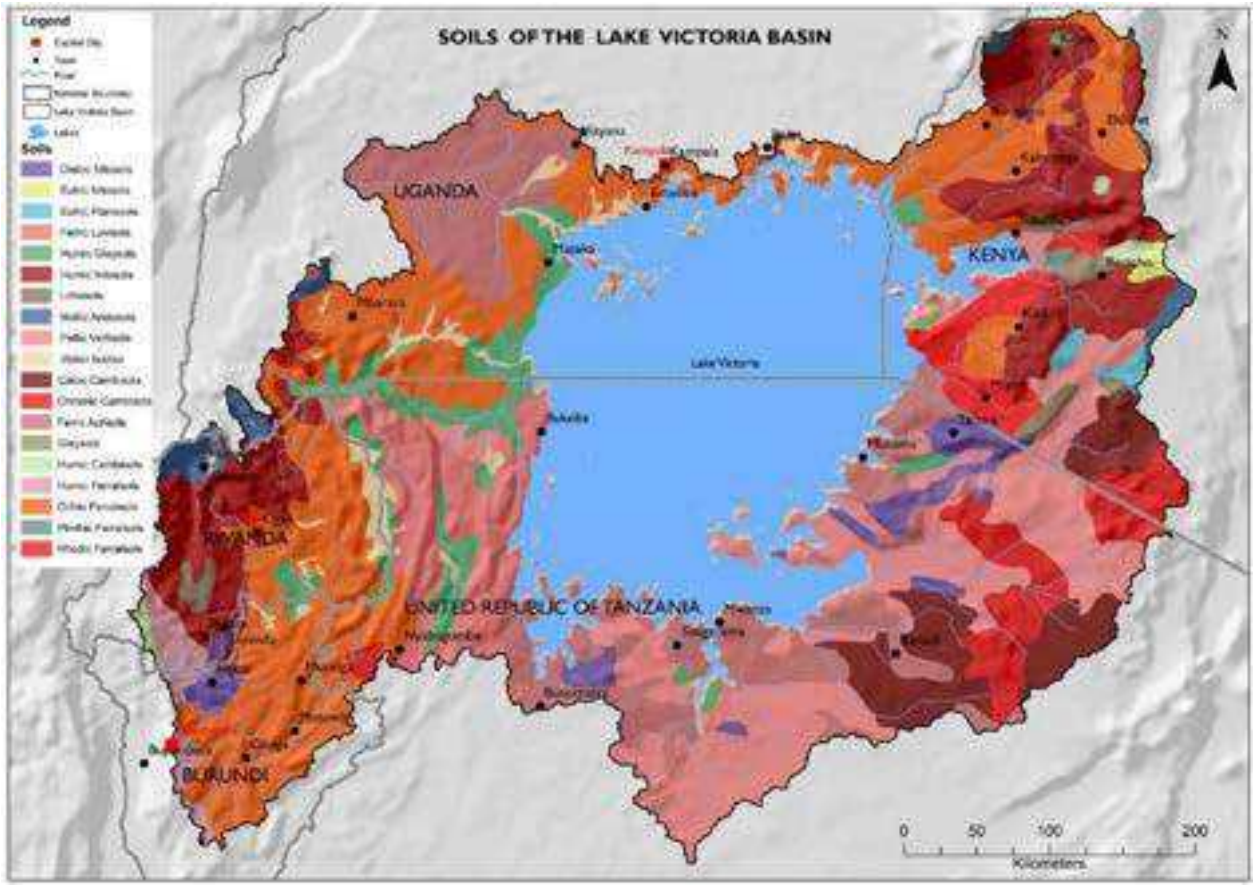


Figure 2-3. *Soils of the Lake Victoria Basin (source: Harmonized World Soil Database, FAO)*

The low fertility and high erodibility of these soils constrain agricultural productivity and accelerate land degradation. Combined with intense rainfall and extensive vegetation clearance, these conditions have produced severe soil erosion and sedimentation, reinforcing a cycle of declining productivity and environmental degradation (Odada et al., 2004; Swallow et al., 2009).

2.1.6 Ecosystems and Biodiversity

The Lake Victoria Basin comprises an ecologically diverse landscape encompassing multiple freshwater and terrestrial ecoregions shaped by topography, climate, and biogeographic history (Olson et al., 2001; Thieme et al., 2005). The dominant terrestrial ecoregion, the Victoria Basin Forest-Savanna Mosaic, extends across approximately 165,800 km² and features extensive savannas, woodlands, and papyrus swamps (Burgess et al., 2004; White, 1983). Additional ecoregions include the Albertine Rift Montane Forests, which exhibit Africa's highest faunal endemism levels (Plumptre et al., 2007), and the Serengeti Volcanic Grasslands, supporting one of Earth's largest remaining unaltered wildlife migrations (Bell, 1971).

Lake Victoria, covering 68,800 km² as the world's largest tropical lake by area, constitutes the basin's ecological heart (Hamilton et al., 2022). The lake's biotic communities have undergone fundamental transformation, particularly its fish assemblages. Once hosting over 500 endemic haplochromine cichlids, the ecosystem now supports a simplified fishery dominated by introduced Nile perch and Nile tilapia alongside native dagaa (Witte et al., 2007; Njiru et al., 2008). This transformation, resulting from deliberate species introductions and eutrophication, precipitated one of modern history's most severe vertebrate mass extinctions (Hecky, 1993).



Figure 2-4. *Two of the cichlid fishes of Lake Victoria – Pundamilia pundamilia and Pundamilia nyererei (source: Selz, 2008, 2009)*

Satellite lakes, including Nabugabo, Kanyaboli, and Ihema, function as critical refugia for native species that disappeared from Lake Victoria following Nile perch predation (Chapman et al., 1996). Extensive wetland systems, predominantly papyrus swamps, provide essential ecosystem services including sediment filtration, nutrient retention, and biodiversity support (Kiwango et al., 2012). These wetlands harbor threatened species such as the Shoebill *(Balaeniceps rex)* and sitatunga *(Tragelaphus spekei)*.

The basin contains numerous protected areas that safeguard its exceptional biodiversity. Designated Ramsar Sites, Important Bird Areas, and national parks—including Nyungwe Forest, Akagera, and the Serengeti-Mara ecosystem—provide critical habitat for rare and endangered species, from mountain gorillas and chimpanzees to papyrus-endemic birds (PFBC-CBFP, 2014; Masozera & Alavalapati, 2004). Montane forests surrounding the basin, particularly the Mau Forest Complex, serve as vital water towers regulating hydrological flows and supporting over 1,400 plant species (Uwiragiye et al., 2023). Collectively, these ecosystems generate services valued at billions of dollars annually, directly sustaining over 45 million people (Nyamweya et al., 2022).

2.2: Demographic Profile

This section examines the demographic foundations of the Lake Victoria Basin, showing how population dynamics influence environmental sustainability, economic development, and governance. Drawing on census and research data, it analyzes population size, growth, distribution, age structure, urbanization, and migration. It underscores both the pressures of rapid population expansion on natural resources and the opportunities offered by a large, youthful population, framing demographics as a key driver of the basin's current challenges and future prospects.

2.2.1 Population Size and Growth Trends

As of 2025, the Lake Victoria Basin supports an estimated 45 million people1, making it one of Africa's most densely populated regions. Population growth within the basin—averaging 3.5 to 3.8 percent per year—significantly exceeds national averages of 2.0 to 2.9 percent in the riparian states (Figure 2-5; World Bank, 2023). Urban centers along the lakeshore are expanding even faster, often surpassing 6 percent annually. According to projections by Nyamweya et al. (2020), the basin's population is expected to at least double by 2050, reaching between 113 and 165 million people. This sustained growth—illustrated in Figures 2-6 and 2-7—will intensify pressure on land, water, and ecosystem services, underscoring the urgency of integrated, sustainable management across the basin.

1 Estimate of the Lake Victoria Basin Commission Secretariat.

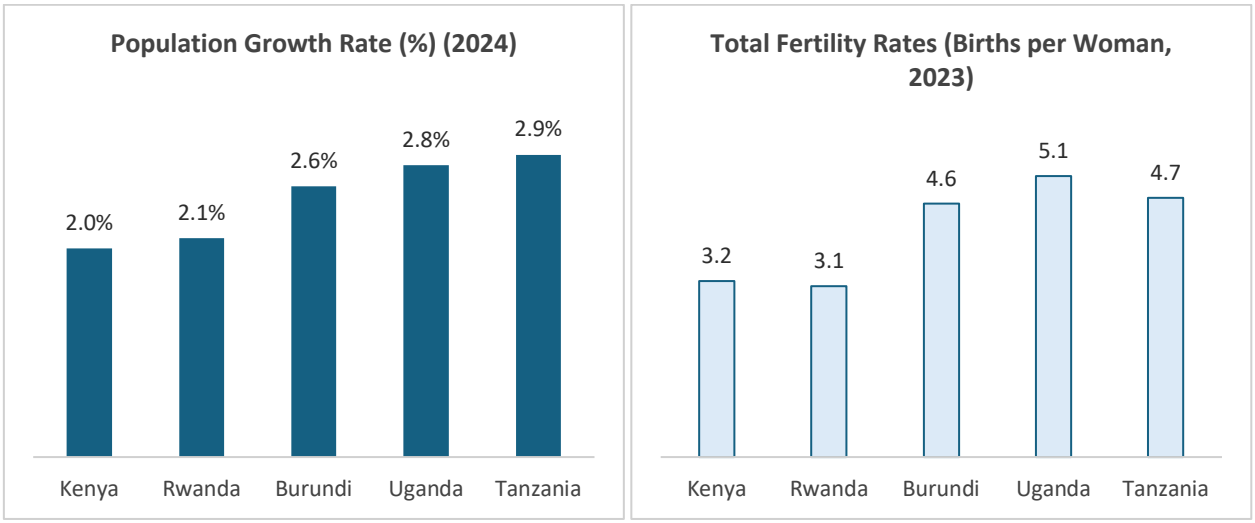


Figure 2-5. *Population growth rates and total fertility rates in the Lake Victoria Basin countries (World Bank 2025).*

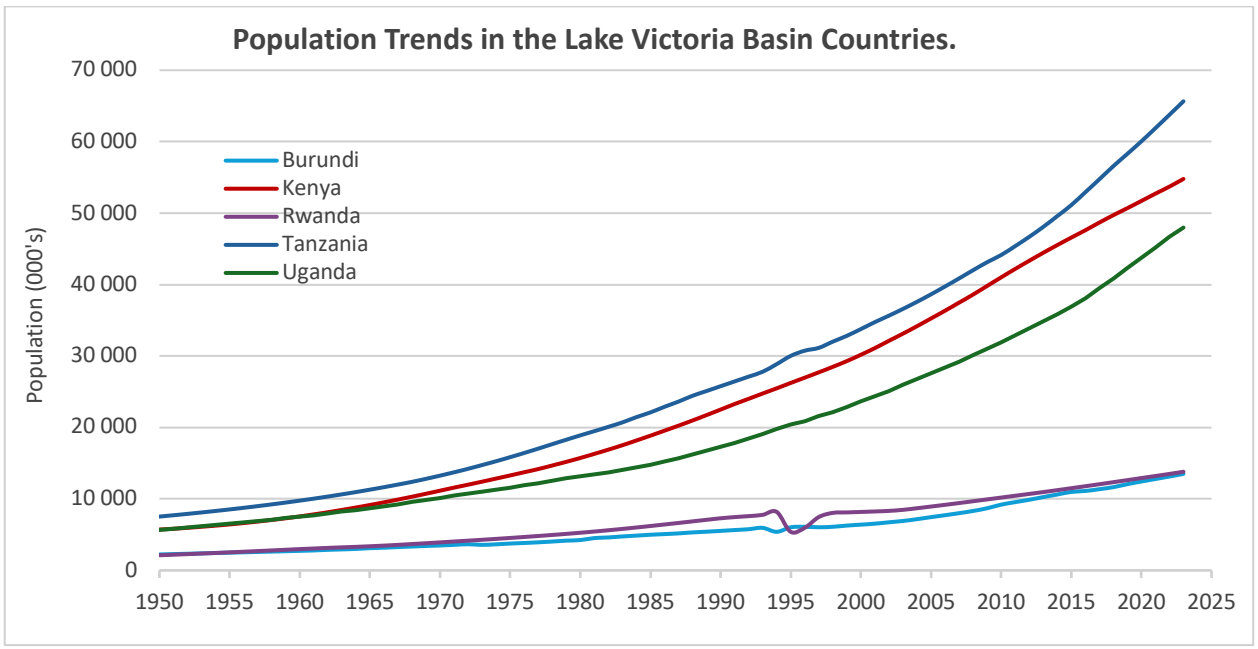


Figure 2-6. *Population trends in the Lake Victoria Basin countries (UNDESA, 2025).*

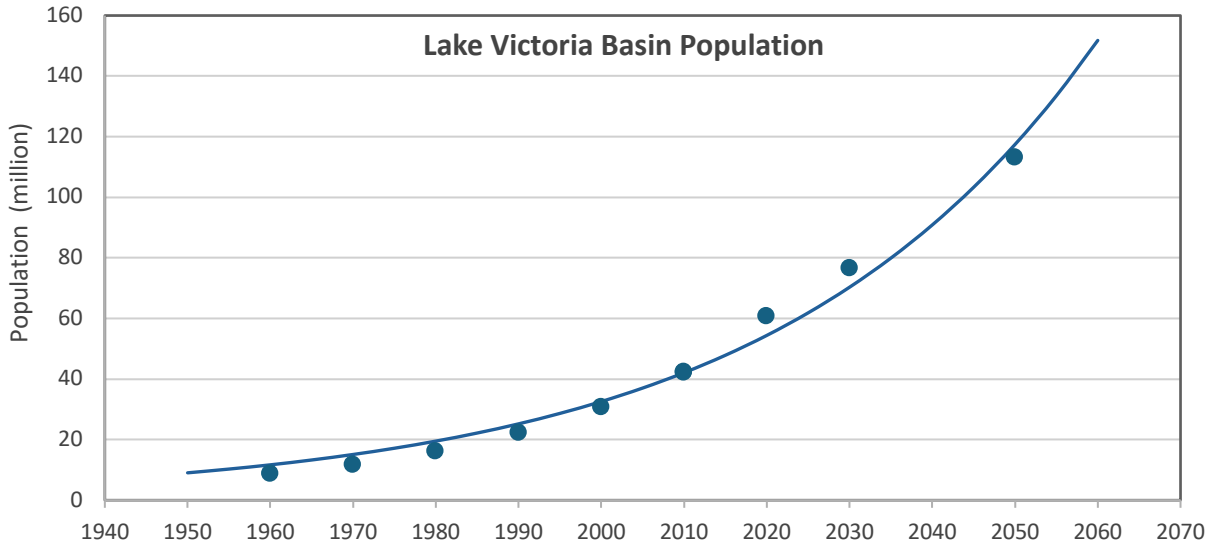


Figure 2-7. *Population trends and projections in the Lake Victoria Basin (Nyamweya et al, 2020)*

2.2.2 Spatial Distribution and Settlement Patterns

Population distribution in the Lake Victoria Basin is highly uneven, forming a landscape of demographic contrasts shaped by ecological potential, historical settlement, and economic opportunity (UNEP, 2006; World Bank, 2023). Dense settlement occurs where fertile soils, rainfall, and access to the lake's resources converge, while sparsely populated zones correspond to protected or less productive lands (Figure 2-8).

> "As of 2025, the Lake Victoria Basin supports an estimated 45 million people, making it one of Africa's most densely populated regions. Population growth within the basin—averaging 3.5 to 3.8 percent per year..."

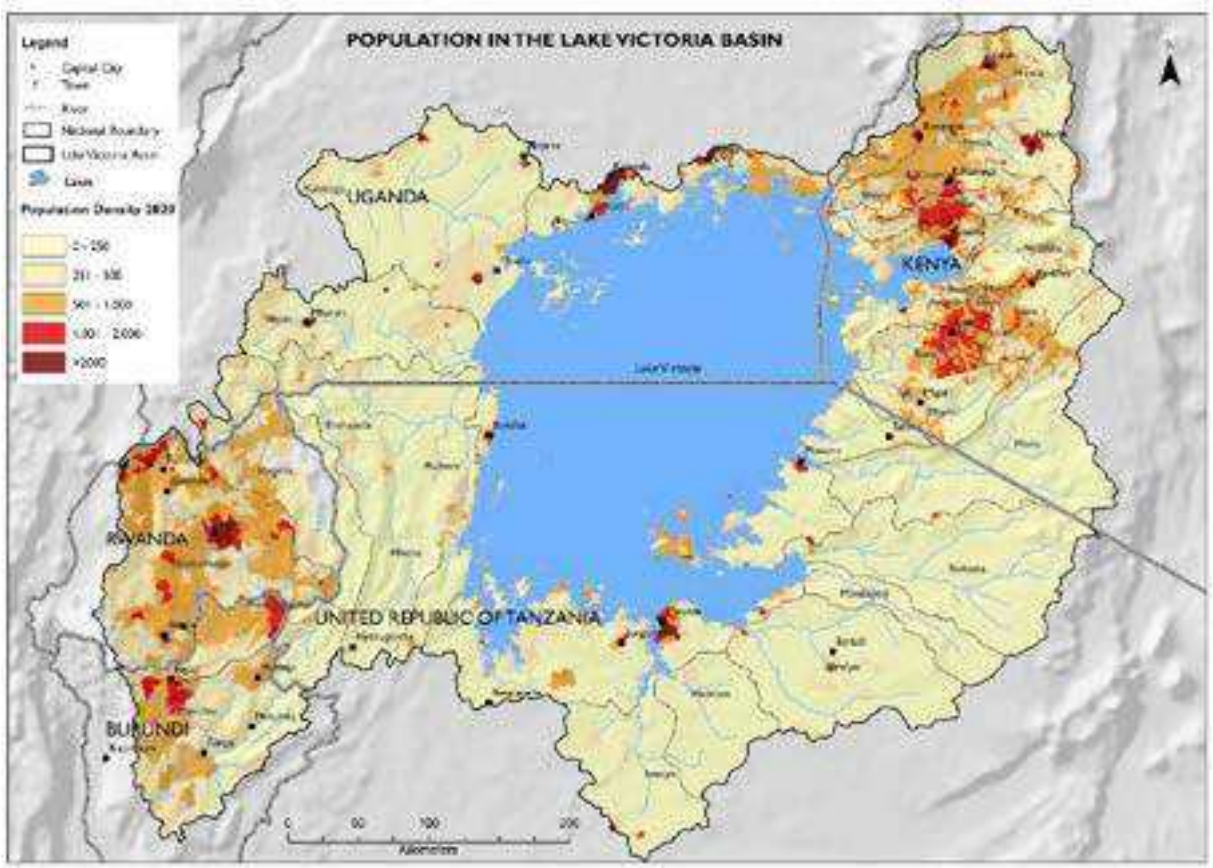


Figure 2-8. *Population density within the Lake Victoria Basin (Source: Gridded Population of the World, Version 4 (GPWv4), CIESIN) Center For International Earth Science Information Network - CIESIN -Columbia University. (2018). Gridded Population of the World, Version 4 (GPWv4):Population Density, Revision 11 (Version 4.11). Palisades, NY: NASA SEDAC.doi:10.7927/H49C6VHW.*

Key areas of population concentration are the following:

- **Lakeshore zones:** A defining feature of the basin is the dense belt of human settlement along its shoreline, drawn by the lake's fisheries, transport routes, and trade opportunities. The fishery—among the world's largest inland fisheries—supports millions of livelihoods, creating strong demographic pull toward the lakeshore (LVBC, 2025).
- **Urban centers:** Major cities such as Kampala, Entebbe, and Jinja (Uganda); Kisumu and Homa Bay (Kenya); Mwanza, Musoma, and Bukoba (Tanzania); and Kigali (Rwanda) act as economic anchors for the basin. Their rapid expansion, often exceeding 6 percent annually, has outpaced infrastructure and service provision (World Bank, 2023).
- **Highland regions:** The fertile highlands of Kenya, Rwanda, and Burundi host intensive agriculture supported by favorable rainfall and volcanic soils. While crucial for food security, runoff from these slopes contributes to sedimentation and nutrient loading in downstream rivers and the lake (World Bank, 2023).

Areas of sparse population are:

- **Protected areas** such as Serengeti, Rubondo, Akagera, and Kakamega Forest remain sparsely settled, serving as ecological buffers.
- **Peripheral rural areas** away from the lakeshore and main roads, similarly consist of dispersed smallholder farms and low-density settlements.

Overall, the Lake Victoria Basin exhibits one of Africa's steepest population-density gradients, from near-zero densities in protected parks and forest reserves to hyper-dense urban cores. On average, the basin hosts ~350 persons2/km², with some pockets approaching exceeding 1,500/km², a pattern that places immense pressure on natural resources and social infrastructure.

The highest concentrations occur around Uganda's Kampala, reaching about 9,100 persons/km² in 2024, with surrounding Wakiso District still dense at roughly 1,800/km²—evidence of a metropolitan area extending beyond city limits. Mwanza on the Tanzanian shore shows similar intensity, averaging over 2,500/km² across its urban councils, while Kigali anchors Rwanda's share of the basin at around 2,400/km², reflecting rapid urbanization and centralized growth. In western Kenya, densely settled highlands such as Vihiga, Kisii, and Kakamega sustain 600–1,000 persons/km² through long-established farming systems. Burundi's densest area, Ngozi (~448/km²), remains lower than neighboring urban peaks but indicates substantial human pressure (UBOS, 2024; KNBS, 2019; NBS and OCGS, 2024; NISR, 2025). These patterns are reflected in sub-catchments, as shown in Table 2-1.

2.2.3 Age Structure and the Demographic Dividend

The Lake Victoria Basin has an exceptionally youthful population, with people under 25 years comprising up to **74%** of the basin's population in Uganda and **65%** in Kenya (Smalley & Mwaipopo, 2021). These figures exceed national averages, where the share of people under 25 ranges from 58% in Rwanda to 66% in Uganda (UNDESA, 2024). The result is a high child-dependency ratio—ranging from 63% in Kenya to 87% in Burundi—which limits household savings, constrains public investment, and heightens demand for education, health, and jobs.

However, this large youth cohort also presents an opportunity for a demographic dividend if fertility declines and the growing workforce is productively employed. *Figure 2-9* shows the population pyramids of the five LVB countries, highlighting early signs of demographic transition, especially in Kenya where fertility rates are falling. *Textbox 2-1* further discusses how the basin's youth can become an engine of inclusive growth, provided sustained investments are made in education, health, and employment creation.

Table 2-1. **Mean population density in the sub-catchments of LVB**

Sub basin Name	Mean Popl. Density (pers/km2)	Sub basin Name	Mean Popl. Density (pers/km2)	Sub basin Name	Mean Popl. Density (pers/km2)
Grumeti	27	Katonga	187	Nzoia	514
Mbalageti	47	Bukora	207	Yala	566
Biharamulo	79	Middle Kagera	316	Nyabarongo	625
Mara	95	Nyando	329	North Awach	631
Lower Kagera	121	Ruvubu	377	Sio	646
Magogo-Moame	125	Sondu	478	Nyashishi	746
Simiyu	133	South Awach	481	Northern shore streams	778
Isanga	138	Gucha-Migori	485		

2 Computed from the NASA gridded population maps, 2020.

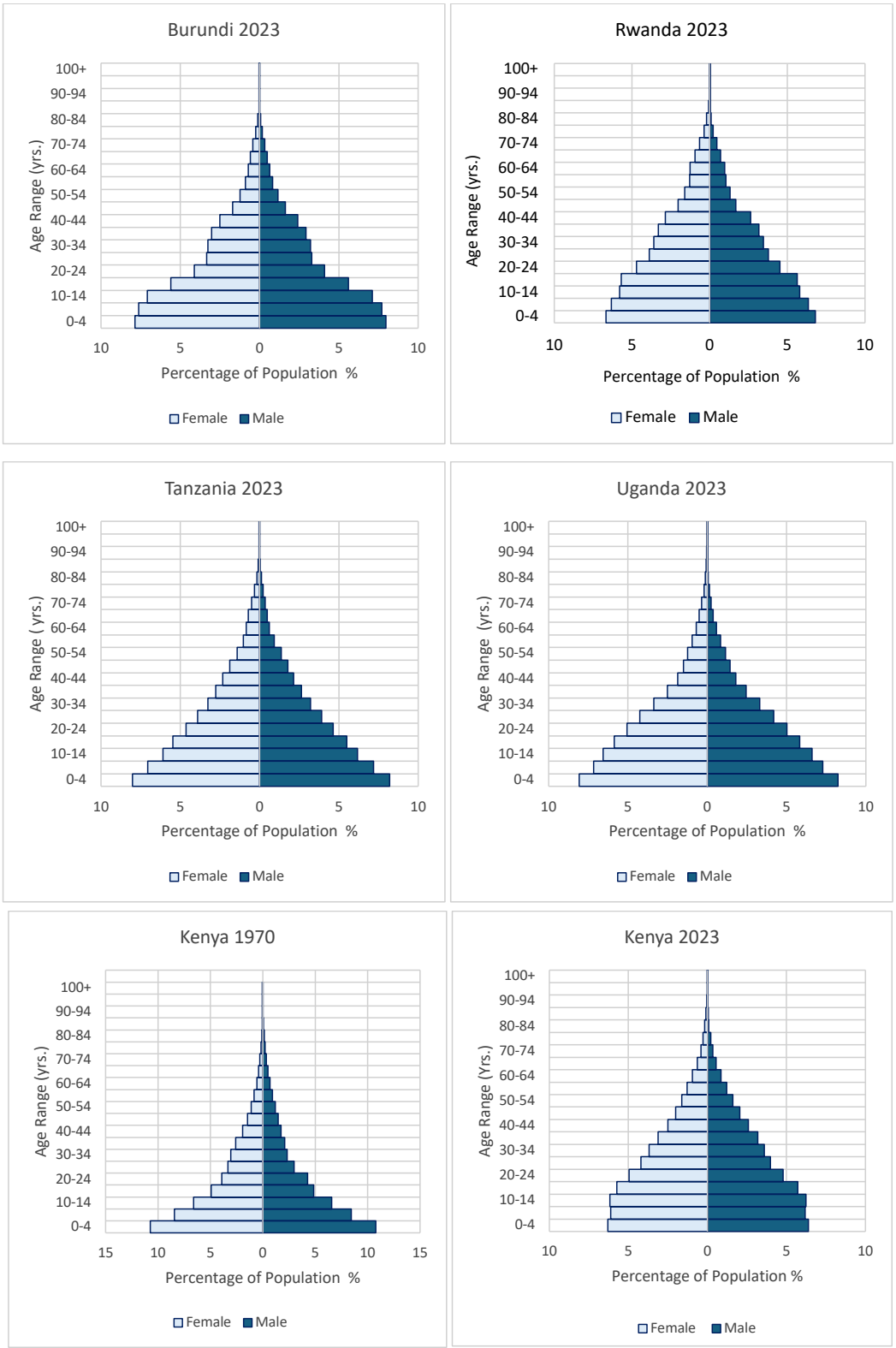


Figure 2-9. *Population pyramids for the Lake Victoria Basin Countries (Source: UNDESA, 2025f)*

Textbox 2-1: Youth as Engine of Inclusive Growth

Across the Lake Victoria Basin, a large share of the population is under 25, and child dependency ratios remain high—signaling both pressure on households now and the potential for a demographic dividend later. If fertility continues to decline and cohorts entering the labor market are healthier and better educated, the age structure can tilt toward a larger, more productive workforce relative to dependents—raising savings, investment, and growth (UNDESA, 2024).

Yet the dividend is **not automatic**. Without sustained investments in education and job creation, a youth-heavy population can intensify land and fisheries pressure, deepen underemployment, strain services, and perpetuate a "poverty–environment trap" (Al Jazeera, 2021; Oucho, 1984). Conversely, equipping young people with skills for sustainable aquaculture, renewable energy, modern agriculture, and ecotourism could transform this demographic burden into an engine for growth and resilience.

2.2.4 Urbanization in the Lake Victoria Basin

The Lake Victoria Basin is experiencing one of Africa's fastest urban transitions, driven by demographic expansion, economic transformation, and environmental change. Home to over 45 million people, the basin's population is projected to more than double by 2050, with much of this growth concentrated in over 100 towns and cities ranging from major lakeside metropolises—Kampala, Kisumu, and Mwanza—to a growing constellation of secondary urban centers (World Bank, 2025). This accelerating shift offers immense opportunities for regional development but also poses profound challenges for environmental sustainability and social inclusion

Urban expansion in the basin is largely unplanned and among the fastest globally, with city populations growing by 4–6 percent annually and the physical footprint of built-up areas increasing by up to 1,000 percent between 1985 and 2014 (UN-Habitat, 2023; Xue et al., 2024). This growth (Figure 2-10) is fueled by natural population increase, declining rural land productivity, and migration toward towns that serve as hubs of trade, industry, and fisheries (Lake Victoria Basin Commission, 2022). The pattern is one of rapid, low-density sprawl that consumes wetlands and agricultural land, outpaces infrastructure provision, and deepens socio-environmental risks.

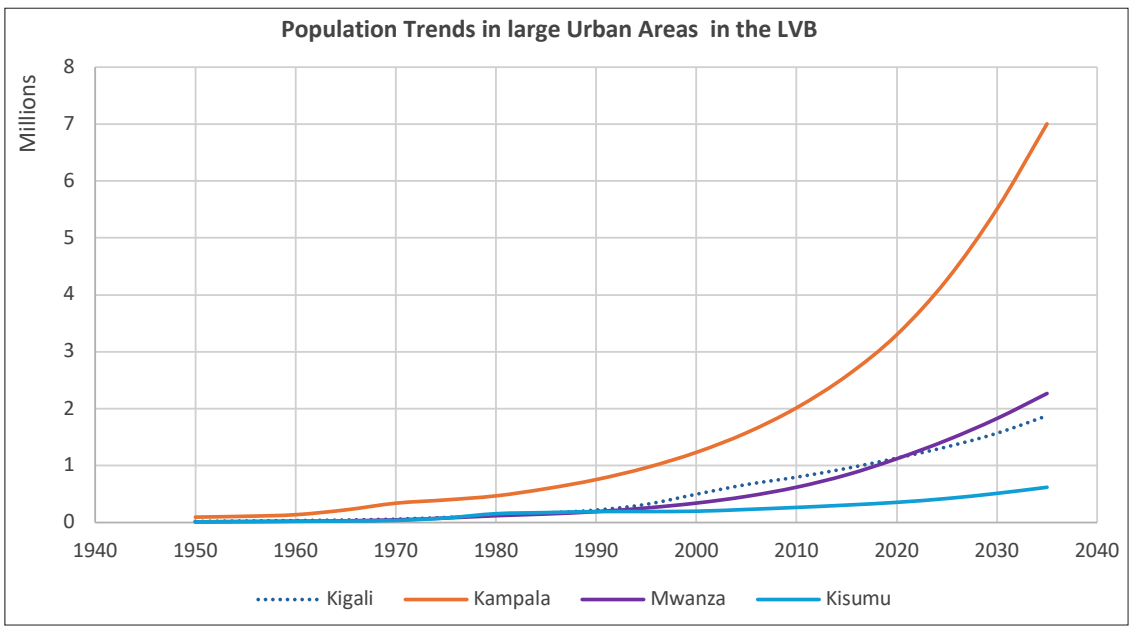


Figure 2-10. *Population trends in four Lake Victoria Basin cities (Source: UNDESA, 2018)*

The region's leading cities illustrate these dynamics vividly. Kampala's unregulated growth has destroyed wetlands and greenspaces, and intensified flooding, leaving over 80 percent of residents in informal settlements. Kigali, though widely praised for its order and cleanliness, faces a severe housing affordability crisis and lacks a central sewerage system (Tumwebaze & Mosler, 2014). Kisumu struggles with solid waste management and youth unemployment nearing 40 percent, while Mwanza's steep terrain and informal settlements complicate sanitation service delivery (Maarifacog, 2024; Economic Policy Research Centre, 2024). Across the basin, more than 60 percent of the urban population lives outside formal planning frameworks, reinforcing vulnerability and inequality.

Unplanned urbanization has precipitated a basin-wide sanitation and pollution crisis. Over 33 million residents lack access to improved sanitation, leading to the continuous discharge of untreated wastewater into Lake Victoria and its tributaries (World Bank, 2025). The resulting nutrient enrichment has caused eutrophication, algal blooms, and biodiversity loss—76 percent of the lake's endemic freshwater species are now endangered (IUCN, 2018). These environmental and social stresses reinforce a "poverty–environment trap," where ecological degradation undermines livelihoods and fuels further unregulated growth. Nonetheless, if well managed, urbanization could become a catalyst for resilience and inclusive growth.

2.2.5 Migration and Mobility

The Lake Victoria Basin (LVB) is one of Africa's most mobile regions, with population movements shaped by economic opportunity, regional integration, conflict, and climate stress. Rural–urban migration, especially among youth, continues to drive rapid urbanization as people seek employment and education in towns and cities (World Bank, 2023). Cross-border mobility is facilitated by the East African Community's Common Market Protocol, which promotes labor and trade flows—though porous borders also heighten security and resource-management challenges (EAC et al., 2023; IOM, 2024). The basin also hosts large refugee and internally displaced populations from neighboring conflict-affected areas, particularly South Sudan, the DRC, and Burundi (IOM, 2024).

Climate change is emerging as a major force shaping future migration. According to *Groundswell Africa* (Rigaud et al., 2021), by 2050 the LVB countries could record **16.6 to 38.5 million internal climate migrants,** equivalent to roughly 10 percent of the projected population, if high-emission and unequal-development pathways persist. Tanzania and Uganda are expected to experience the largest numbers—up to 16.6 million and 12 million respectively—followed by Kenya (7.6 million), Rwanda (1.2 million), and Burundi (1.0 million). Climate "in-migration" hotspots are projected along the Lake Victoria shoreline, central Rwanda, and parts of Kenya's Rift Valley, while "out-migration" hotspots will likely occur in water-stressed or flood-prone zones such as coastal Tanzania, Mombasa, and northwestern Uganda.

These patterns suggest that migration within the basin will increasingly be driven by the search for viable livelihoods in a changing climate. Without climate-resilient and inclusive development, unplanned urbanization and ecosystem degradation could reinforce cycles of vulnerability, poverty, and conflict. Integrating climate-informed mobility into basin-wide planning will therefore be critical to managing population dynamics sustainably.

2.2.6 Synthesis: Demographic Opportunities and Challenges for Sustainable Development

The Lake Victoria Basin (LVB) stands at a demographic crossroads. Rapid population growth, a pronounced youth bulge, and largely unplanned urbanization are intensifying pressure on the basin's ecosystems and livelihoods. If unmanaged, these forces could entrench a "poverty–environment trap," characterized

by overfished waters, degraded lands, and declining agricultural productivity (World Bank, 2018). High dependency ratios continue to strain household savings, investment, and public services, while fast-growing urban centers such as Kampala, Kisumu, and Mwanza face severe infrastructure deficits, pollution, and the expansion of informal settlements (Lwasa, 2022). Climate change compounds these risks, with projections suggesting that up to 38 million people in the basin countries could be displaced by 2050, heightening competition for land and water (Rigaud et al., 2021).

Yet this demographic momentum also presents transformative potential. A young and expanding workforce can drive innovation, entrepreneurship, and regional integration if matched with investment in education, health, and green job creation (World Bank, 2018). Well-managed urbanization can foster economic diversification and reduce pressure on fragile rural landscapes, while empowering women and youth in sustainable agriculture, fisheries, and ecotourism can turn communities into active stewards of natural resources.

The choice before the region is stark. The path ahead is decisive. Without coordinated investments, population growth will deepen poverty and environmental decline. With strategic action—expanding education, family planning, skills training, and green infrastructure—the basin's youthful population can become a powerful driver of sustainable and inclusive growth.

2.3: The Basin Economy and Livelihoods

This section examines the economic landscape and livelihood systems of the Lake Victoria Basin, highlighting its dual identity as both a regional growth engine and a zone of persistent vulnerability. It explores the basin's vast natural wealth—its fertile lands, fisheries, minerals, and hydropower potential—and the key sectors driving its economy, including agriculture, fisheries, energy, mining, transport, and tourism. The section also assesses employment patterns, informality, and livelihood strategies, emphasizing the challenges of youth unemployment, gender inequality, and environmental degradation. Finally, it outlines strategic pathways for transitioning toward a sustainable and inclusive blue-green economy that balances productivity, equity, and ecological integrity across the East African region.

2.3.1: Lake Victoria Basin: A Region of Promise and Paradox

The Lake Victoria Basin (LVB) occupies a place of extraordinary strategic importance within East Africa. Endowed with vast natural capital—fertile soils, favourable climate, rich biodiversity, and the world's second-largest freshwater lake—it sustains the livelihoods of over 45 million people and supports some of the most densely populated rural areas in Africa (Awange, 2021; World Bank, 2022).

Recognizing this potential, the East African Community (EAC) has designated the basin a *Regional Economic Growth Zone* and *Area of Common Economic Interest*, mandating coordinated, cross-border development to transform it into a driver of shared prosperity (EAC, 2019). Yet this vision coexists with deep-rooted poverty and accelerating environmental degradation. A large share of the population still lives below the international poverty line, even as pressures from population growth, land use change, and pollution intensify (Awange, 2021; World Bank, 2022).

The basin thus embodies a central paradox: immense natural and economic potential constrained by ecological stress and socio-economic vulnerability. Understanding and addressing this interdependence between economic activity and environmental sustainability remains critical to realizing the LVB's promise.

2.3.2 The Macroeconomic Engine of the Region

The Lake Victoria Basin (LVB) is the economic heart of the East African Community, anchoring food, water, and energy security for over 56 million people. Its wealth of natural resources—fertile land, freshwater, minerals, and biodiversity—underpins livelihoods and regional integration, even though much of its value remains undercounted in national statistics (Awange, 2021; World Bank, 2022).

Key Economic Sectors:

- **Agriculture:** The basin's main employer, supporting more than 70% of residents and contributing over 30% to national GDPs. Smallholder rain-fed farming dominates (Figure 2-11), producing staples (maize, cassava, beans, rice) and cash crops (tea, coffee, sugar). Yet declining soil fertility, shrinking landholdings, and poor input use drive low productivity and land degradation, while expansion into wetlands and hillsides accelerates erosion and nutrient loading into the lake. Scaling irrigation, soil restoration, and climate-smart practices is vital for sustainable growth (FAO, 2007; World Bank, 2025).



Figure 2-11. *A family of smallholder farmers in Rwanda (source:annonymous)*

- **Fisheries & Aquaculture:** Lake Victoria supports one of the world's largest inland fisheries—about one million tons annually, valued near USD 1.12 billion and sustaining over three million people (Kayanda et al., 2017). Overfishing and pollution have depleted stocks, spurring aquaculture growth. Managed expansion and rehabilitation of wild fisheries are essential to balance livelihoods with ecosystem health.
- **Mining:** The Lake Victoria Goldfields—spanning Tanzania, Kenya, and Uganda—host major gold deposits alongside diamonds, tin, and tungsten. Industrial mines generate up to 10% of Tanzania's GDP, while artisanal mining employs hundreds of thousands but causes mercury pollution and social risks (Human Rights Watch, 2013; USGS, 2023).



Figure 2-12. *A fisherman casting a net in Lake Victoria, Uganda*

- **Energy:** The Victoria Nile hydropower cascade (Nalubaale, Kiira, Bujagali) supplies nearly all Uganda's electricity and exports power to neighbors, while the Rusumo Falls project enhances regional access. Heavy dependence on hydropower, however, exposes the basin to climate-driven lake-level variability (Awange, 2021).
- **Transport & Industry:** Lake Victoria's waterways move goods worth USD 6 billion annually, with modernization of ports and ferries offering large untapped potential. Yet inefficiencies, pollution, and weak regulation persist. Agro-processing and fish-processing industries add value but remain major pollution sources (World Bank, 2022).

- **Tourism**: Tourism is a vital economic pillar in the Lake Victoria Basin (LVB), contributing about 10% to regional GDP and 7% to employment. Kenya and Tanzania dominate through mature safari and coastal markets, Uganda is diversifying rapidly, Rwanda follows a high-value, low volume model, and Burundi's sector remains nascent (Kenya Association of Travel Agents, 2024; The Great Lakes Eye, 2025). Growth is constrained by environmental degradation, poor infrastructure, and security risks that limit investment and accessibility (World Bank, 2016). Strengthened cooperation under the East African Community's Visit East Africa: Feel the Vibe initiative and harmonized regional policies could unlock the basin's potential as a sustainable, transboundary tourism destination (East African Community, 2025).

2.3.3 Overall Contribution to the Regional Economy

Estimating the GDP of a transboundary region such as the Lake Victoria Basin (LVB) is complex, yet available assessments underscore its immense economic weight. The basin's annual output is estimated at about USD 164 billion, positioning it as the most economically dynamic region in East Africa (ICON-Invest, 2017). This represents dramatic growth from early 2000s estimates of only USD 3–5 billion.

When compared to the combined GDP of the five riparian states—approximately USD 273 billion in 2024 (World Bank, 2024) (Figure 2-14)—the LVB contributes nearly 60% of the region's total economic activity. This highlights its central role not only as a shared ecosystem but as the core engine of the East African regional economy.



Figure 2-13. *MV Sigulu -a ferry on Lake Victoria operated by the Ministry of Works, Uganda (Source:)*

In summary, the Lake Victoria Basin is both the region's economic powerhouse and its greatest sustainability challenge. Realizing its promise demands integrated management that balances productivity, environmental protection, and social equity.

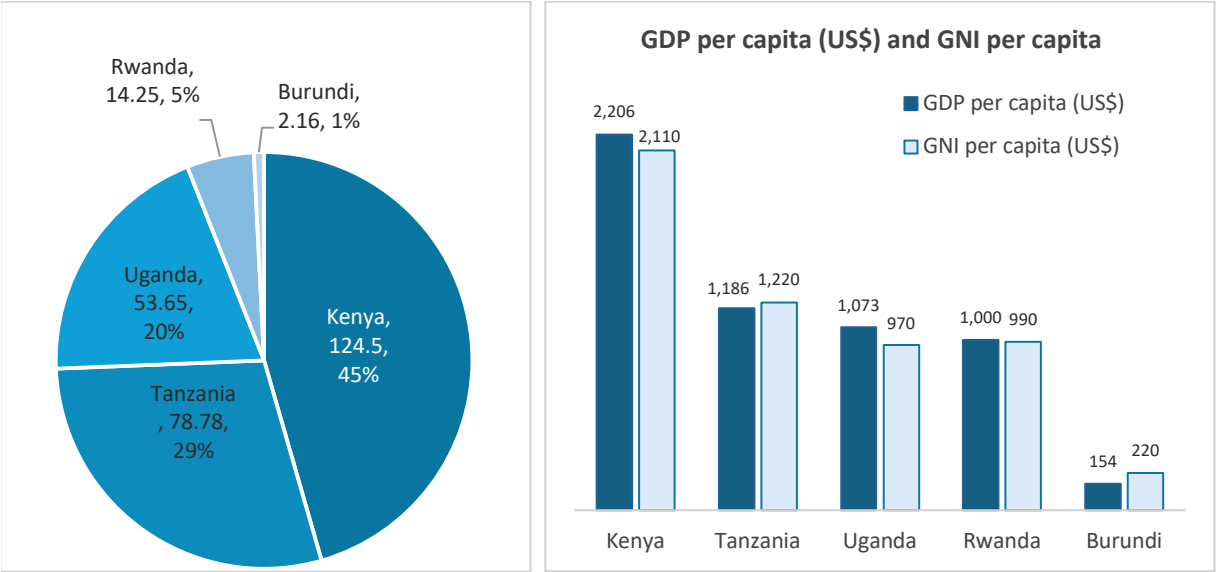


Figure 2-14. *[Left] Contribution of countries to the combined GDP of the LVB states. [Right] Other macroeconomic indicators of LVB Partner States (2023/2024 estimates) (Source: World Bank, IMF, national statistics offices (Kenya National Bureau of Statistics; National Institute of Statistics of Rwanda; Uganda Bureau of Statistics).*

2.3.4 Employment and Livelihood Strategies

The Lake Victoria Basin (LVB) economy remains predominantly rural and natural-resource based. While endowed with vast productive potential, most livelihoods are informal, low-income, and vulnerable to environmental and economic shocks.

Key Features of Employment and Livelihoods:

- **Sectoral Structure:** Agriculture dominates employment—above 60% in Tanzania and Uganda, and over 80% in Burundi (*see Table 2-2*). Rwanda and Kenya are more diversified, with larger service and small industrial sectors (World Bank, 2024; ILO, 2023).
- **High Informality:** Informal work exceeds 85% of total employment across all countries, reflecting limited formal job creation and rapid population growth. For most households, informality provides subsistence but little security or productivity.

Table 2-2. Employment Structure in the Lake Victoria Basin Partner States

Country	Employment in Agriculture (% of total)	Employment in Industry (% of total)	Employment in Services (% of total)	Informal Employment (% of total)
Kenya	32.3 (2023)	15.6 (2023)	52.2 (2023)	83.0 (2021)
Uganda	~60 (2021)	10.9 (2015)	32.1 (2015)	87.9 (2021)
Tanzania	63.0 (2018)	7.3 (2018)	29.7 (2018)	93.3 (2020)
Rwanda	43.5 (2023)	16.7 (2023)	39.8 (2023)	90.4 (2024)
Burundi	>85 (est.)	N/A	N/A	98.3 (2014)



Figure 2-15. *Informal workers in the Lake Victoria Basin*

- **Gender and Participation:** Female participation remains lower than male across the basin, with women concentrated in low-paid, informal, or care-based activities. Employment-to-population ratios average 50–55% for men and 35–45% for women.
- **Youth Employment:** The region's youthful population faces chronic underemployment—youth joblessness exceeds 15% in most countries and is highest in urban centres such as Kisumu and Kampala. Limited vocational skills and access to finance constrain opportunities.
- **Livelihood Diversification:** Households combine farming, fishing, livestock, petty trade, and wage labour to manage risk. Emerging activities such as aquaculture, beekeeping, and biogas production provide alternative incomes while easing pressure on land and fisheries (FAO, 2007).
- **Vulnerability and Social Exclusion:** Persons with disabilities and many women in fishing communities remain highly marginalized, often excluded from asset ownership and formal credit.

In summary, employment in the LVB is extensive but precarious—dominated by smallholder agriculture, pervasive informality, and deep youth and gender disparities. Unlocking inclusive growth will require structural transformation, skills development, and greener livelihood options aligned with sustainable resource management.

2.3.5 Pathways to a Sustainable and Inclusive Basin Economy

The Lake Victoria Basin (LVB) stands at a critical turning point. Home to over 45 million people, it anchors East Africa's economy, yet the same sectors that sustain its population—subsistence farming, overfishing, and informal labor—are depleting the natural capital on which its future depends. Without change, poverty, inequality, and environmental degradation will intensify.

The basin's challenges are interlinked: a heavy dependence on extractive and climate-sensitive resources; unsustainable farming that drives soil erosion, sedimentation, and lake pollution; unequal fisheries value chains; widespread low-productivity informal employment; and persistent exclusion of women and youth from economic opportunities.

A sustainable transition calls for a shift from extractive to regenerative growth. This includes rebuilding fish stocks through better regulation; adding value to fish products to increase incomes and reduce waste; expanding responsible aquaculture; and investing in safe lake transport and eco-tourism. On land, climate-smart agriculture, renewable energy, and waste recycling can enhance productivity while curbing degradation, complemented by large-scale ecosystem restoration to stabilize hydrology and strengthen climate resilience.

The transition depends on four strategic priorities:

1. **Integrated watershed management** to balance agriculture, fisheries, and ecosystem health.
2. **Inclusive value chains** that empower cooperatives and expand access to finance and markets for women and youth.
3. **Human capital development** aligned with emerging sectors such as aquaculture, tourism, renewable energy, and digital services.
4. **Strengthened transboundary governance** through an empowered LVBC to harmonize policies and guide evidence-based decisions.

Pursuing these pathways will enable the LVB to transform from a region of fragile promise into a resilient blue-green economy—delivering shared prosperity while safeguarding its ecological foundation.

2.4: Human Development and Social Services

This section examines the state of human development and social well-being in the Lake Victoria Basin, focusing on progress and persistent gaps in key sectors that shape quality of life. It reviews trends in the Human Development Index (HDI), education, health, water and sanitation, housing, and poverty, highlighting both improvements and enduring inequalities across and within the riparian states. The analysis underscores how environmental degradation, demographic pressure, and limited infrastructure constrain access to essential services, especially for rural, youth, and marginalized populations and concludes by calling for integrated, transboundary actions to advance inclusive and sustainable human development in the basin.

2.4.1 Human Development Index (HDI) Trends in the Basin

The Lake Victoria Basin (LVB), faces the dual challenge of advancing human development under severe demographic and environmental strain. With population densities averaging about 350 persons/km²—and surpassing 1,500 persons/km² in urban centers—demand for education, health, water, housing, and jobs continues to outpace supply. Nearly 80 percent of residents depend on climate-sensitive livelihoods such as rainfed agriculture and fisheries, heightening vulnerability to resource degradation and climate shocks (UNDP, 2025; GRID-Arendal & LVBC, 2022).

The Human Development Index (HDI) measures progress in health, education, and living standards. According to UNDP (2025), all five LVB countries have made gradual gains, though disparities remain stark. Kenya leads with an HDI of 0.628 (rank 143), followed by Uganda (0.582; rank 157), Rwanda (0.578; rank 159), and

Tanzania (0.555; rank 165), all in the "Medium" category. Burundi, at 0.439 (rank 187), remains in the "Low" category. Long-term trends show notable progress from low baselines—Rwanda's HDI nearly doubled between 1995 and 2023, and Uganda's rose by 70% since 1990. However, inequality erodes these gains: the Inequality-Adjusted HDI reduces Kenya's score by 27% and Burundi's by 35%, reflecting deep disparities in access to services and opportunities.

The modest HDI gains despite rich natural resources reflect a persistent poverty–environment trap. Unsustainable practices such as overfishing, deforestation, and pollution degrade key livelihoods, while poor water and soil quality undermine health and incomes. Without stronger environmental governance, development gains will remain fragile (GRID-Arendal & LVBC, 2022).

Overall, human development in the LVB remains below global averages and highly vulnerable to climate shocks. Breaking this cycle requires integrated approaches that combine improvements in health, education, and livelihoods with sound resource management and climate resilience.

2.4.2 Education

Education is a cornerstone of human development in the Lake Victoria Basin (LVB), yet persistent gaps in quality, equity, and progression continue to limit its transformative potential. While access to basic education has improved across the riparian states, disparities in literacy, gender equality, and school completion remain major obstacles to inclusive growth.

Literacy Rates

Literacy levels vary widely across the basin. Kenya leads with an adult literacy rate of 92.5%, followed by Tanzania (83%), Rwanda (79%), Burundi (75.5%), and Uganda (74%) (Kenya National Bureau of Statistics [KNBS] & Ministry of Health [MoH], 2023; National Bureau of Statistics [NBS], 2024; Uganda Bureau of Statistics [UBOS], 2024).

Persistent gender and rural–urban divides—especially in Burundi and Tanzania—continue to disadvantage women and rural populations. Within countries, strong subnational contrasts, such as Uganda's Buganda region (86%) versus Busoga (72%), highlight uneven progress even among lake-adjacent communities.

Fishing communities, despite their vital economic role, remain among the least literate. Rates are far below national averages, particularly for women and youth, due to child labor, migration, and limited school infrastructure.

Enrolment, Attendance, and Completion

Primary enrolment is near universal, but retention and transition to higher levels remain weak. Kenya enrolled 9.1 million pupils in primary and 4.1 million in secondary schools in 2023 (KNBS, 2024). Uganda's primary enrolment is 78%, but secondary participation falls to 23% (CPAR Uganda, 2025). Tanzania's lower secondary completion is around one-third, while Burundi's remains below 35% for both sexes (UNESCO, 2022).

Gender Parity

Gender parity is largely achieved at primary level—Burundi's Gender Parity Index (GPI) reached 1.00 in 2017 (ISTEEBU et al., 2017)—but inequalities persist at secondary level. Kenya shows steady progress (KNBS, 2024), while in Burundi and Tanzania early marriage and adolescent pregnancy continue to hinder girls' education (ISTEEBU et al., 2017; Tanzania NBS et al., 2023).

Textbox 2-2: The "Leaky Pipeline" and Youth Challenge



The basin's large youth population could yield a demographic dividend, but education gaps threaten this potential. High primary enrolment gives way to steep drop-offs at secondary and tertiary levels, leaving most youth with only basic education. The African Development Bank (2023) highlights a profound mismatch between graduates' skills and labour market demands across East Africa, a key factor in high youth unemployment. This is compounded by limited labor market opportunities: over 10 million young Africans enter the workforce annually, competing for just 3 million formal jobs. The result is widespread underemployment and vulnerability to social instability. Without major investment in secondary, vocational, and skills-based education, the youth bulge risks becoming a liability rather than a driver of growth (UNDP, 2024).

2.4.3 Health Status

Health conditions in the Lake Victoria Basin (LVB) have improved in recent decades, but the region continues to face a heavy disease burden, fragile health systems, and stark inequalities. Environmental stress, poverty, and population growth remain key determinants of poor outcomes (WHO, 2023).

> "Fishing communities, despite their vital economic role, remain among the least literate. Rates are far below national averages, particularly for women and youth, due to child labor, migration, and limited school infrastructure."

Mortality Trends

Under-five mortality has declined but remains above global targets—43 per 1,000 live births in Tanzania, 45 in Rwanda, 52 in Uganda, and 78 in Burundi, compared with the SDG benchmark of 25 (ISTEEBU et al., 2017; NISR et al., 2021; UBOS, 2023; Ministry of Health et al., 2023). Maternal mortality shows similar disparities, ranging from 189 deaths per 100,000 live births in Uganda to nearly double that level in Burundi (see *Figure 2-16*)., reflecting continued gaps in skilled care and emergency obstetric services (UBOS, 2023; World Bank, n.d.). These patterns highlight persistent inequities in access and quality of care across the basin.

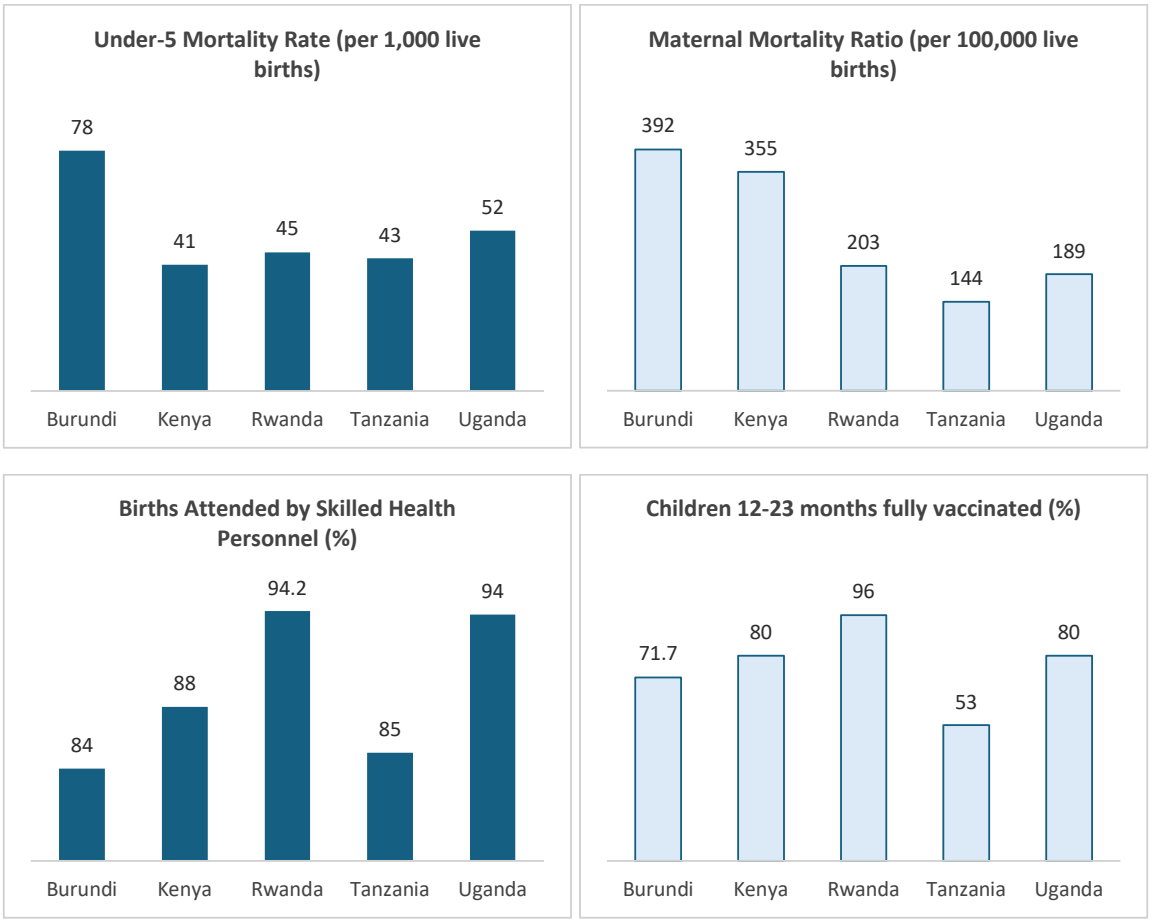


Figure 2-16. *Some health indicators for the Lake Victoria Basin Countries.*

Sources: *ISTEEBU et al. (2017); KNBS & ICF (2023); Ministry of Health et al. (2023); NISR et al. (2021); UBOS (2023); MOH, NBS, OCGS and ICF, 2023. Note: Data years vary by country and indicator, representing the most recent available figures.*

Disease Burden and Access

Malaria, HIV/AIDS, and water-borne infections dominate the region's health profile. HIV prevalence in fishing communities is up to three times higher than national averages, while cholera, diarrhoea, and schistosomiasis remain widespread due to inadequate sanitation and polluted waters (KNBS & ICF, 2023; Ministry of Health et al., 2023). Access to healthcare has expanded but remains uneven—Kenya's 15,000 health facilities are unevenly staffed, and vaccination coverage ranges from 71% in Burundi to 96% in Rwanda (NISR et al., 2021; WHO, 2023).

Environmental–Health Linkages

Degraded ecosystems, stagnant waters, and untreated effluents exacerbate disease transmission. These environmental and socio-economic stressors reinforce each other, creating a cycle of ill-health and poverty that undermines human development. Breaking this cycle requires integrated basin-wide strategies linking health investments with improved water quality, sanitation, and environmental management (WHO, 2023).

2.4.4 Water Supply and Sanitation Coverage

Access to safe water, sanitation, and hygiene (WASH) underpins health, productivity, and ecosystem integrity. While all Lake Victoria Basin (LVB) countries have expanded basic services, progress toward safely managed water and sanitation remains slow, with persistent urban–rural and gender disparities (World Health Organization [WHO] & United Nations Children's Fund [UNICEF], 2023).

Drinking Water

Access to at least basic water services is relatively high—90% in Kenya, 80% in Rwanda, 68% in Uganda, 61% in Tanzania, and 62% in Burundi. However, safely managed water, which ensures consistent and contamination-free supply, is far lower. Urban residents fare better than rural ones: in Kenya, 95% of urban residents have access versus 86% in rural areas; in Uganda, the gap is 89% against 62%. For rural women and girls, long distances and queuing times for water collection continue to constrain education and livelihoods (WHO & UNICEF, 2023).



Figure 2-17. *A woman and child fetching water from a river*

Sanitation and Open Defecation

Sanitation coverage lags well behind water access. In 2022, only 34% of Kenya's population and 22% of Uganda's had access to basic sanitation, compared with 64% in Rwanda (WHO & UNICEF, 2023). Safely managed sanitation remains rare, and most wastewater is discharged untreated into the environment. Open defecation persists among 15% of Ugandans and 11% of Tanzanians, with the highest rates in rural areas. Urban centres also struggle, as sewer systems and treatment capacity have not kept pace with population growth.

Implications

Inadequate WASH services and high open defecation rates continue to fuel disease outbreaks and lake pollution. Chronic underinvestment in infrastructure—especially sewerage, treatment plants, and rural water systems—remains a major bottleneck. Weak coordination and enforcement further impede progress. Social and cultural norms, stigma around latrine use, and limited hygiene education also hinder sanitation uptake. Addressing these challenges demands a twin approach: scaling up investment in climate-resilient infrastructure while promoting behavioral change, community engagement, and stronger local governance.

2.4.5 Housing and Basic Infrastructure

Housing quality and access to modern infrastructure are central to well-being, but both remain limited in the Lake Victoria Basin (LVB) due to poverty, rural settlement patterns, and low investment. Most homes are self-built using traditional materials, offering poor protection against weather, disease, and displacement.

Census data indicate predominantly rural, single-storey housing across the basin. In Tanzania, 94% of dwellings are single-level, though 75% now have a registered address (National Bureau of Statistics [NBS], 2022). Kenya and Rwanda report gradual adoption of modern building materials, but rural households still rely heavily on mud, wood, and thatch (Kenya National Bureau

of Statistics [KNBS], 2023; National Institute of Statistics of Rwanda [NISR], 2024). In Burundi, durable housing remains unaffordable for most, and displacement from conflict and climate shocks has left many in temporary shelters.

2.4.6 Poverty and Inequality Levels

Despite its rich natural resources, the Lake Victoria Basin (LVB) remains marked by deep poverty and inequality. Monetary and multidimensional deprivation converge to limit economic and social progress, particularly in rural areas dependent on rainfed agriculture and weak infrastructure.



Monetary Poverty

Poverty remains widespread across the Lake Victoria Basin (LVB), despite moderate national economic growth. Using the updated international poverty line of US$3.00 per day (2021 PPP), the share of people living in poverty reaches 74% in Burundi, 64% in Rwanda, 60% in Uganda, 51% in Tanzania, and 46% in Kenya (World Bank, 2020, 2025). These figures highlight the widespread vulnerability of households, especially those reliant on subsistence agriculture and informal employment.

National poverty data mirror this pattern while exposing stark subnational disparities. In Kenya, 39.8% of people lived below the national poverty line in 2022, rising to over 50% in Busia County (Kenya National Bureau of Statistics [KNBS], 2024). In Uganda, poverty fell to 16.1% nationally in 2023/24 but reached 29.4% in Busoga along the lake's northern shore (Uganda Bureau of Statistics [UBOS], 2024). Rwanda's 2024 survey reported 27.4% nationally and over 37% in the Western Province bordering the basin (National Institute of Statistics of Rwanda [NISR], 2025).

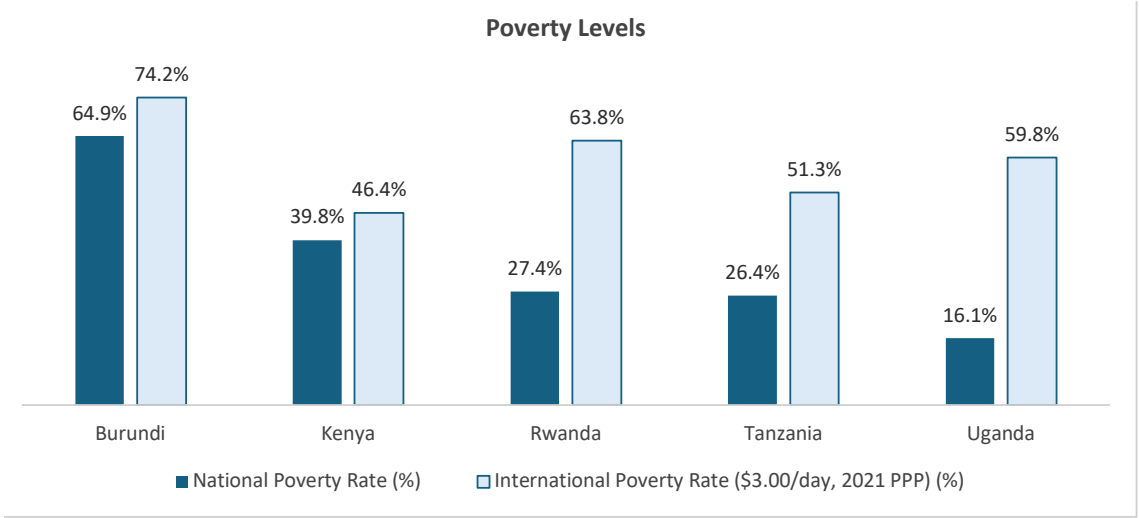


Figure 2-18. *Poverty levels in the LVB countries rated against the national poverty line and international poverty line Some health indicators for the Lake Victoria Basin Countries.*

Sources: *Independent Publications Uganda (2024); Kenya National Bureau of Statistics (2025); National Institute of Statistics of Rwanda (2025a) World Bank (2020c)*

Overall, poverty in the basin is predominantly rural and spatially concentrated, driven by limited infrastructure, low agricultural productivity, and weak market linkages.

Multidimensional Poverty

Income measures understate deprivation. The Multidimensional Poverty Index (MPI) shows that between 48% and 81% of basin populations face overlapping deprivations in health, education, and living standards (Oxford Poverty and Human Development Initiative [OPHI], 2023; UNICEF & ISTEEBU, 2023). Lack of clean water, electricity, and quality education traps households in cycles of poor health and limited opportunity that income growth alone cannot break.

Inequality

Economic growth across the Lake Victoria Basin (LVB) has not translated into equitable gains. The Gini Index remains high—43.7 in Rwanda, 42.7 in Uganda, and 40.5 in Tanzania—indicating pronounced income inequality (World Bank, 2023). These disparities reflect deep structural divides by geography, gender, and wealth, which continue to limit access to quality education, modern energy, and productive employment, particularly for rural and low-income households.

2.4.7 Conclusion

The human development profile of the Lake Victoria Basin shows progress in education and child survival but enduring deficits in poverty reduction, health, and access to basic services. Natural wealth has yet to yield broad human well-being.

Three themes define this landscape. First, an environment–poverty trap persists, as resource degradation erodes health, agriculture, and livelihoods. Second, multidimensional poverty—spanning education, WASH, and energy—reinforces vulnerability. Third, deep inequalities between urban and rural areas, genders, and wealth groups limit the inclusiveness of growth.

Breaking these cycles calls for integrated, transboundary action: combining environmental management with expanded social services, improving access to secondary and vocational education, and investing in rural infrastructure, especially clean energy and sanitation. Sustainable progress will depend on the Partner States' shared commitment to manage resources equitably and extend the benefits of growth to all.

Table 2-3. **Poverty and Inequality Indicators in LVB Countries**

Indicator	Burundi	Kenya	Rwanda	Tanzania	Uganda	Year
MPI Headcount Ratio (UNDP, %)	72.9	38.9	48.8	57.1	54.9	2016-17 / 2014 / 2019-20 / 2015-16 / 2016
Intensity of Deprivation (UNDP, %)	56.4	46.9	47.3	51.0	54.2	2016-17 / 2014 / 2019-20 / 2015-16 / 2016
Gini Index	38.6	39.0	43.7	40.5	42.7	2013 / 2021 / 2016 / 2018 / 2019

***Sources**: World Bank (2021, 2023, 2024); UNDP (2024); OPHI (2023); CPAR Uganda (2025). Note: Years for MPI and Gini Index vary based on the latest available survey data for each country*

Implications

High poverty, structural deprivation, and inequality reinforce one another, constraining inclusive growth. Reducing these gaps requires targeted rural investment, equitable access to education and health services, and policies that expand opportunities for women and marginalized groups. Without addressing inequality directly, economic growth will continue to bypass much of the basin's population.

2.5 Infrastructure and Connectivity

This section examines how physical and digital connectivity shape economic performance and regional integration in the Lake Victoria Basin (LVB). It consolidates evidence from national statistics, regional observatories, and continental initiatives to assess three pillars—transport (road, rail, lake), energy systems, and ICT networks. The analysis evaluates service coverage, reliability, and cost; identifies binding constraints including financing gaps, maintenance backlogs, and climate vulnerability; and highlights opportunities for coordinated, cross-border solutions under the LVBC/EAC framework and continental programs such as PIDA. The aim is to provide a rigorous, decision-ready basis for prioritizing resilient, pro-poor infrastructure investments.

2.5.1 The significance of regional infrastructure and connectivity

The Lake Victoria Basin (LVB) is central to East Africa's integration agenda, designated by the East African Community as a Regional Economic Growth Zone and Area of Common Economic Interest (LVBC, 2021). The region holds an estimated annual trade potential of US $60 billion, presenting a significant opportunity for coordinated, cross-border investment aimed at optimizing logistics and unifying transport systems (LVBC, 2024).

Regionally, the Programme for Infrastructure Development in Africa (PIDA) identifies the LVB's corridors, power pools, and digital networks as vital foundations for continental competitiveness. With economic growth increasing demand on existing stock, the African Development Bank (AfDB) advocates for accelerated investment, regulatory harmonization, and enhanced private-sector participation (AfDB, 2023).

Mobilizing capital is a priority, as current infrastructure investment in Sub-Saharan Africa hovers around 3.5 percent of GDP. Bridging this gap to meet Sustainable Development Goals offers a pathway to robust economic health (World Bank Group, 2023; AfDB, 2025). Furthermore, integrating climate-resilient design into basin-wide planning is essential to safeguard hydropower and transport networks against changing weather patterns, ensuring long-term connectivity and economic stability (Cascades, 2025).

2.5.2 Transport networks (road, rail, lake transport)

Transport networks act as the arteries of commerce in the LVB, determining trade efficiency and market access. Strengthening the integration of roads, railways, and lake transport is a primary strategy for reducing logistics costs and supporting the landlocked economies of Uganda, Rwanda, and Burundi (COMESA Business Council, 2022).

Road Infrastructure

Roads serve as the primary mode for passenger and cargo movement. The Northern Corridor (Mombasa–Kampala–Kigali) and Central Corridor (Dar es Salaam–Mwanza–Kigali/Bujumbura) are being fortified by significant investments, such as highway upgrades in Kenya and the Kampala–Entebbe Expressway in Uganda (EAC, 2023a). Further connectivity is being explored through AfDB-backed feasibility studies for projects like the Kisumu–Busia–Malaba expressway (AfDB, 2016). Complementing these major arteries, the focus is also shifting toward improving rural access roads to connect smallholder farmers to markets, alongside developing sustainable financing models for preventive maintenance (EAC, 2023b).

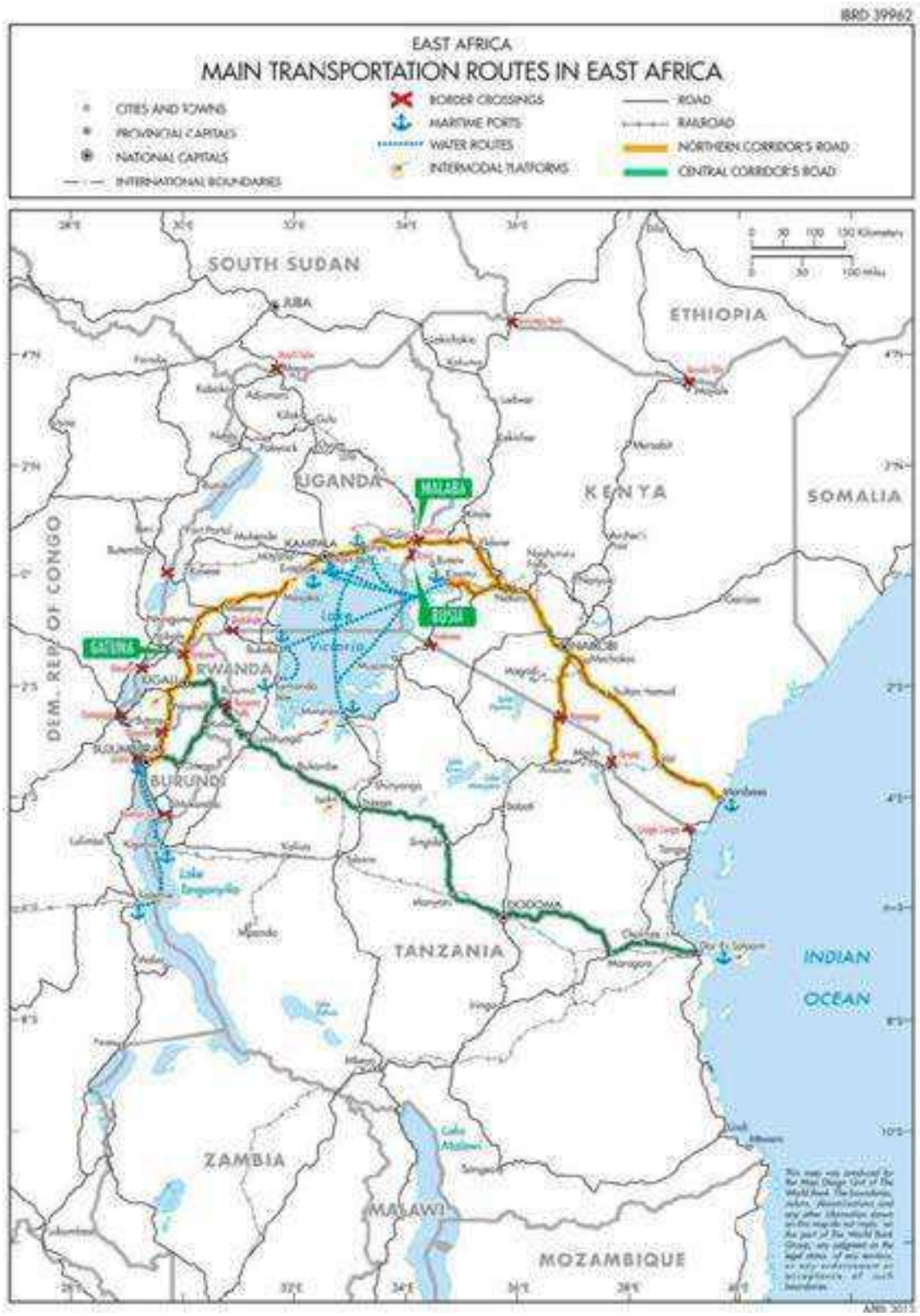


Figure 2-19. *The Northern and Central Corridors in East Africa (The World Bank)*

Railway Systems

The railway sector is undergoing a transformative transition. The integration of new Standard Gauge Railways (SGRs) in Kenya and Tanzania with existing Meter Gauge Railways (MGRs) is a key focus area for improving freight efficiency and interoperability. As Tanzania advances its SGR network and Kenya optimizes freight to Naivasha, the region is seeing enhanced strategic positioning of both the Northern and Central Corridors to facilitate smoother inland cargo movement (COMESA, 2021).

Lake Transport and Ports

Lake Victoria offers strong potential as a low-cost, high-volume regional logistics hub. Development efforts are therefore focusing on optimizing key ports—Kisumu (Kenya), Mwanza (Tanzania), and Uganda's Port Bell alongside the emerging Bukasa Port—where modernization is addressing long-standing constraints related to infrastructure, cargo handling, and safety systems (LVBC, 2024). Initiatives such as the AfDB's Multinational Lake Victoria Maritime Transport Project are strengthening navigation safety and operational efficiency through improved navigation aids, rescue centers, and expanded communications coverage (AfDB, 2016). Upgrades at Bukasa Port in particular are designed to integrate lake transport with rail and road networks, supporting the emergence of a fully multimodal regional transport system (LVBC, 2025).

2.5.3 Energy Access and Sources

Energy is both an enabler of development and a persistent constraint in the Lake Victoria Basin (LVB). Despite substantial renewable resources, the basin remains energy-poor, with traditional biomass—primarily firewood and charcoal—still dominating household energy use in most Partner States. This reliance underpins basic cooking and heating needs but drives deforestation and watershed degradation while exposing households, particularly women and children, to severe indoor air pollution and associated health risks (IEA, 2022a).

Electricity Access and Reliability

Electricity access has expanded rapidly over the past decade but remains highly uneven. Kenya and Rwanda have achieved near-universal urban coverage through sustained national electrification programs, while access in Uganda, Tanzania, and especially Burundi lags far behind, with stark rural–urban disparities. In several countries, grid extension has outpaced actual household connections, and even connected users face frequent outages and voltage instability. These reliability deficits significantly weaken the developmental benefits of electrification for households, public services, and productive sectors (World Bank, 2024a; 2025a).

Hydropower: Backbone and Vulnerability

Hydropower remains the backbone of electricity generation across the basin, supplying the majority of grid power in Uganda, Rwanda, and Burundi and substantial shares in Kenya and Tanzania (Figure 2-18) (IEA, 2023a). Major investments have rapidly expanded installed capacity, particularly in Uganda and Tanzania. However, heavy dependence on hydropower exposes national energy systems to increasing climate variability. More frequent droughts, floods, and erratic rainfall are undermining reservoir reliability and power output, amplifying risks to both energy security and broader economic stability.



Figure 2-20. *A truck transporting goods from Mombasa to Kampala at a weighbridge at Malaba border post.*

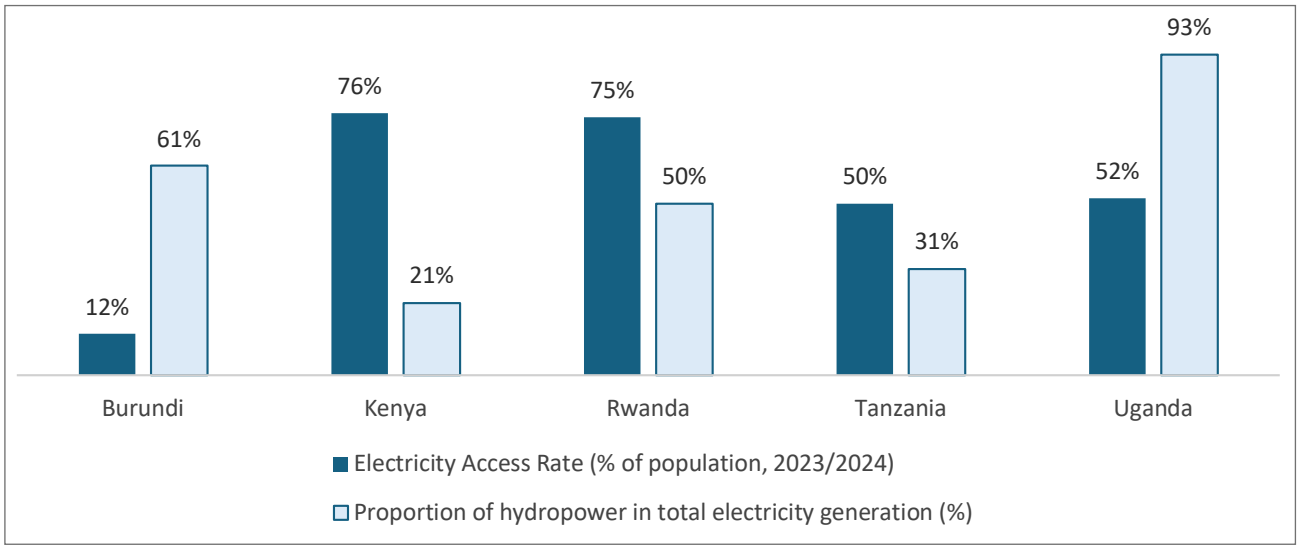


Figure 2-21. *Electricity access rate and proportion of hydropower in total electricity generation in the Lake Victoria Basin Countries.*

Sources: *Ecofin Agency, 2025; World Bank, 2024a; World Bank Group, 2024); Niyonkuru et al., 2024; IEA, 2023; Clean Energy 4 Africa, 2022; SACREEE, (2021); ERA, 2023.)*

Diversification and Renewable Opportunities

Reducing climate and system risks requires accelerated diversification of the energy mix. Kenya demonstrates the potential of this transition, with geothermal power now providing nearly half of its electricity, supported by growing solar and wind capacity (IRENA, 2024). Other Partner States are pursuing geothermal prospects and utility-scale solar and wind, but high upfront exploration costs, grid constraints, and limited storage capacity continue to slow deployment (IRENA, 2022).

Off-Grid and Decentralized Energy Solutions

Decentralized renewable systems have become central to rural electrification, accounting for a large share of new connections across Sub-Saharan Africa. Pay-as-you-go solar markets and community mini-grids—particularly in Kenya and Rwanda—have expanded access in remote areas, though affordability remains a binding constraint for poorer households. Achieving universal access will require substantial additional investment and targeted subsidies to ensure inclusivity (World Bank, 2024b).

Toward a Sustainable and Inclusive Energy Future

Meeting the basin's energy needs demands a shift toward integrated energy security strategies that prioritize clean cooking, rural access, and system resilience. Key priorities include scaling decentralized renewables, reducing over-reliance on hydropower, strengthening regional power trade through the Eastern Africa Power Pool, and deploying innovative financing instruments. Concessional finance, results-based mechanisms, and blended finance facilities can crowd in private investment while safeguarding affordability for vulnerable populations (AfDB, 2025).

2.5.4 ICT and Digital Infrastructure

Alongside energy and transport, digital infrastructure has become a core pillar of connectivity in the Lake Victoria Basin (LVB), underpinning trade, governance, education, and social inclusion. Mobile and broadband networks have expanded rapidly under national regulatory oversight, yet ICT's transformative potential remains constrained by persistent digital divides in affordability, access, and skills.

Connectivity and Use

Mobile penetration is high across the basin, reflecting widespread multi-SIM ownership, but effective internet use remains uneven. While Kenya and Rwanda approach universal 4G coverage, active internet usage lags significantly behind network availability, particularly in Uganda and Burundi. High handset and data costs, coupled with limited digital literacy, now outweigh infrastructure gaps as the main barriers to inclusion, pointing to the need for demand-side policies that improve affordability and skills (Freedom House, 2024; World Bank, 2024).

Backbone Infrastructure and Resilience

Regional connectivity depends on submarine cables landing at Mombasa and Dar es Salaam and inland fiber extensions linking landlocked Partner States to global networks. These investments have reduced latency and costs but remain vulnerable to external shocks, as highlighted by recent Red Sea cable disruptions. Enhancing resilience requires diversified routes, redundancy, and cost-reducing measures such as open-access and shared-infrastructure models, including co-deployment along power and transport corridors (Africa Finance Corporation, 2025).

Regional Integration and Cybersecurity

Digital integration initiatives under the EAC and COMESA—such as the Single Digital Market, EARDIP, and EGEE-ICT—are harmonizing broadband policy, enabling cross-border digital services, and strengthening data governance. Reforms like the One Network Area illustrate the benefits of coordination. However, deeper interconnection also amplifies cyber risks, making regional cybersecurity frameworks and incident-response mechanisms essential to safeguard a resilient and trusted digital ecosystem.

2.5.5 Regional Integration and Cross-Border Infrastructure Initiatives

Transport, energy, and digital systems converge at the core of regional integration in the Lake Victoria Basin (LVB). Once nationally oriented, these networks are increasingly being developed as shared regional platforms under the EAC and LVBC frameworks, enabling cross-border trade, energy security, and digital exchange.

Strategic Corridors and Border Facilities

The Northern and Central Corridors remain the basin's principal economic arteries, linking Mombasa and Dar es Salaam to inland markets. Targeted investments have upgraded trunk roads, ports, and border facilities, while One-Stop Border Posts at key crossings have significantly reduced clearance times and transaction costs. Performance monitoring tools introduced by the EAC have improved transparency and accountability, although non-tariff barriers, inconsistent standards, and regulatory fragmentation continue to constrain corridor efficiency. Ongoing harmonization initiatives, including regional axle-load and border management agreements, are critical to sustaining recent gains. The Table 2-4 and Textbox 2-3 below summarizes some of the major integration projects in the Lake Basin.

Table 2-4. Major Cross-Border Infrastructure Projects in the Lake Victoria Basin

Project Name	Countries Involved	Sector	Status (as of 2024/2025)	Key Details/ Capacity	Key Financiers/Partners
East African Crude Oil Pipeline (EACOP)	Uganda, Tanzania	Transport (Pipeline)	Under Construction (>50% complete)	1,443 km heated crude oil pipeline	TotalEnergies, CNOOC, UNOC, TPDC, Afreximbank
Regional Rusumo Falls Hydroelectric Project	Burundi, Rwanda, Tanzania	Energy (Generation)	Operational	80 MW generation, shared equally	World Bank, African Development Bank (AfDB)
Tanzania-Burundi SGR	Tanzania, Burundi	Transport (Rail)	Planned (Uvinza-Musongati section)	Standard-Gauge Railway link	CCTTFA, AfDB
Kenya-Uganda SGR	Kenya, Uganda	Transport (Rail)	Planned (Malaba-Kampala section)	Standard-Gauge Railway link	NCTTCA, Governments of Kenya & Uganda
EAPP: Burundi-Tanzania Interconnector	Burundi, Tanzania	Energy (Transmission)	Feasibility Study	220 kV transmission line (Horezo-Kigoma)	World Bank (World Bank, 2024d)
EAPP: Ethiopia-Kenya Interconnector	Ethiopia, Kenya	Energy (Transmission)	Operational	500 kV HVDC line, 2,000 MW capacity	AfDB, World Bank (Eastern Africa Power Pool, 2021)

Textbox 2-3: Flagship Transboundary Projects



Photo: *The EACOP pipeline under construction (source: infrastructure.go.ug)*

Two flagship projects in the Lake Victoria Basin region exemplify how large-scale infrastructure can catalyze cooperation, investment, and integration across borders:

- **Rusumo Falls Hydroelectric Project** – Located on the Kagera River, this 80 MW run-of-river hydropower plant was jointly developed by Burundi, Rwanda, and Tanzania under the **Nile Equatorial Lakes Subsidiary Action Program (NELSAP**) framework, with financing and technical support from the **African Development Bank** and the **World Bank.** Electricity generated is shared equally among the three countries, reinforcing regional energy integration.

The project incorporated strong environmental and social safeguards, notably a comprehensive **Livelihood Restoration Program** for affected households, which is widely regarded as good practice and should be emulated in future transboundary infrastructure projects to address social impacts effectively. The decision to adopt a smaller 80 MW run-of-river design, rather than a large reservoir, reflected a deliberate effort to minimize ecological disruption and involuntary resettlement, making Rusumo a flagship example of responsible, cooperative regional development.

- **East African Crude Oil Pipeline (EACOP) –** is a landmark transboundary infrastructure project designed to enable Uganda to commercialize oil discovered in the Albertine Graben by transporting crude to international markets. Stretching 1,443 km from Hoima in western Uganda to the Port of Tanga in Tanzania, it is the world's longest heated crude oil pipeline, engineered to keep waxy crude above 50 °C. Managed by East African Crude Oil Pipeline Ltd as a multinational joint venture, the project integrates advanced engineering, robust legal frameworks, and extensive environmental and social safeguards. By early 2026, construction had reached about 79% completion, with commissioning targeted for mid-2026. Beyond oil transport, EACOP is promoted as a catalyst for regional integration, employment, infrastructure development, and long-term fiscal revenues for both countries

Energy Interconnection and Power Pooling

Regional power interconnections are reinforcing integration beyond national generation systems. Through the East African Power Pool, LVB countries are progressively linking their grids, enabling electricity trade and improving system reliability. Existing and planned interconnectors allow hydropower-dependent systems to balance climate risks by accessing more diverse regional energy sources, strengthening both energy security and climate resilience.

Persistent Gaps and Strategic Priorities

Despite clear progress, integration remains constrained by limited long-term financing, uneven implementation capacity, and climate-related risks to infrastructure durability. Addressing these challenges requires basin-wide planning and stronger coordination. Key priorities include aligning road, rail, and lake transport through an integrated multimodal framework; mobilizing blended finance for climate-resilient transboundary infrastructure; accelerating harmonization of regional energy and digital markets; and reinforcing LVBC's role as a coordinating platform for equitable and environmentally sound infrastructure development. Together, these actions will consolidate connectivity gains and strengthen the basin's contribution to East Africa's long-term integration and sustainable growth

2.6 The Lake Victoria Basin at a Crossroads: Synthesis, Outlook and Strategic Pathways

The Lake Victoria Basin (LVB) is the ecological and economic heart of the East African Community (EAC)—a transboundary landscape that sustains over 45 million people and generates nearly 60 percent of the combined GDP of the five Partner States. Designated by the EAC as a "Regional Economic Growth Zone," the basin integrates hydrology, ecosystems, and livelihoods across Burundi, Kenya, Rwanda, Tanzania and Uganda. Yet its immense natural wealth coexists with widespread poverty, rapid population growth, and accelerating environmental degradation—a paradox now defining the basin's development trajectory (UNDP, 2025; World Bank, 2025).

2.6.1 State of the Basin: Pressure and Potential

As detailed in previous subsections (Sections 2.1–2.5), the LVB's biophysical and socio-economic systems are under intense strain. Population growth (3.5–3.8 % annually) and unplanned urbanization (>6 % per year in many towns) are driving land fragmentation, wetland conversion, and pollution hotspots. Agriculture employs over 70 % of residents but faces declining soil fertility and shrinking farm sizes; the lake's fisheries, once among the world's richest, are showing stock decline from overfishing and eutrophication (Kayanda et al., 2017). Energy systems remain vulnerable to climate variability (Section 2.5.3), while rapid urban sprawl overwhelms sanitation and solid-waste infrastructure (Section 2.4.4).

Despite this, the basin retains enormous potential. It is the headwaters of the White Nile and a hub for regional commerce, hydropower and digital integration (Sections 2.5.2–2.5.5). If well managed, its fertile catchments, youthful labour force and strategic location can propel green industrialization and regional resilience. But current trends—environmental degradation and growing inequality—threaten to erode these gains. HDI values remain low (0.439–0.628), and service access is unequal across and within countries (UNDP, 2025; WHO & UNICEF, 2023). Climate change is expected to amplify pressures, potentially displacing up to 38 million people internally across the five countries by 2050 (Rigaud et al., 2021).

2.6.2 The Core Challenge: The Poverty–Environment Trap

The LVB is caught in a self-reinforcing poverty–environment trap. Most households depend on depleting natural resources for subsistence, while limited infrastructure, weak market access, and informality (> 85 % of employment) constrain economic transformation (Section 2.3.4). Unsustainable farming and fishing practices degrade ecosystems that support livelihoods, reducing resilience to climate shocks and undermining long-term growth. This cycle links closely to structural inequalities outlined in Section 2.4.6—gender, youth, and rural disadvantage perpetuate low productivity and environmental stress. Breaking this trap demands a shift from extractive to regenerative development models that value ecosystem services as economic assets.

2.6.3 Strategic Pathways for a Resilient and Prosperous Basin

Building on the evidence presented throughout this chapter, three interconnected pathways stand out for transforming the basin's trajectory:

1. **Invest in Human Capital and a Regenerative Economy.**

   The youth bulge (Sections 2.2.3 and Textbox 2-1) is the basin's greatest asset if matched with skills, innovation, and green jobs. Shifting from resource extraction to a blue-green economy requires investment in climate-smart agriculture, sustainable aquaculture,

eco-tourism, and renewable energy (OECD, 2020; World Bank, 2022). Such investments will reduce pressure on land and waters while enhancing incomes and gender equity.

2. **Close the Resilient Infrastructure Gap.** Infrastructure deficits identified in Section 2.5 remain the binding constraint to inclusive growth. Priority areas include sanitation and wastewater management to curb lake pollution; multimodal transport corridors linking road, rail and port systems; and decentralized clean energy for rural households. Integrating climate-resilient design into projects under the LVBC and EAC frameworks can maximize shared benefits (AfDB, 2025).

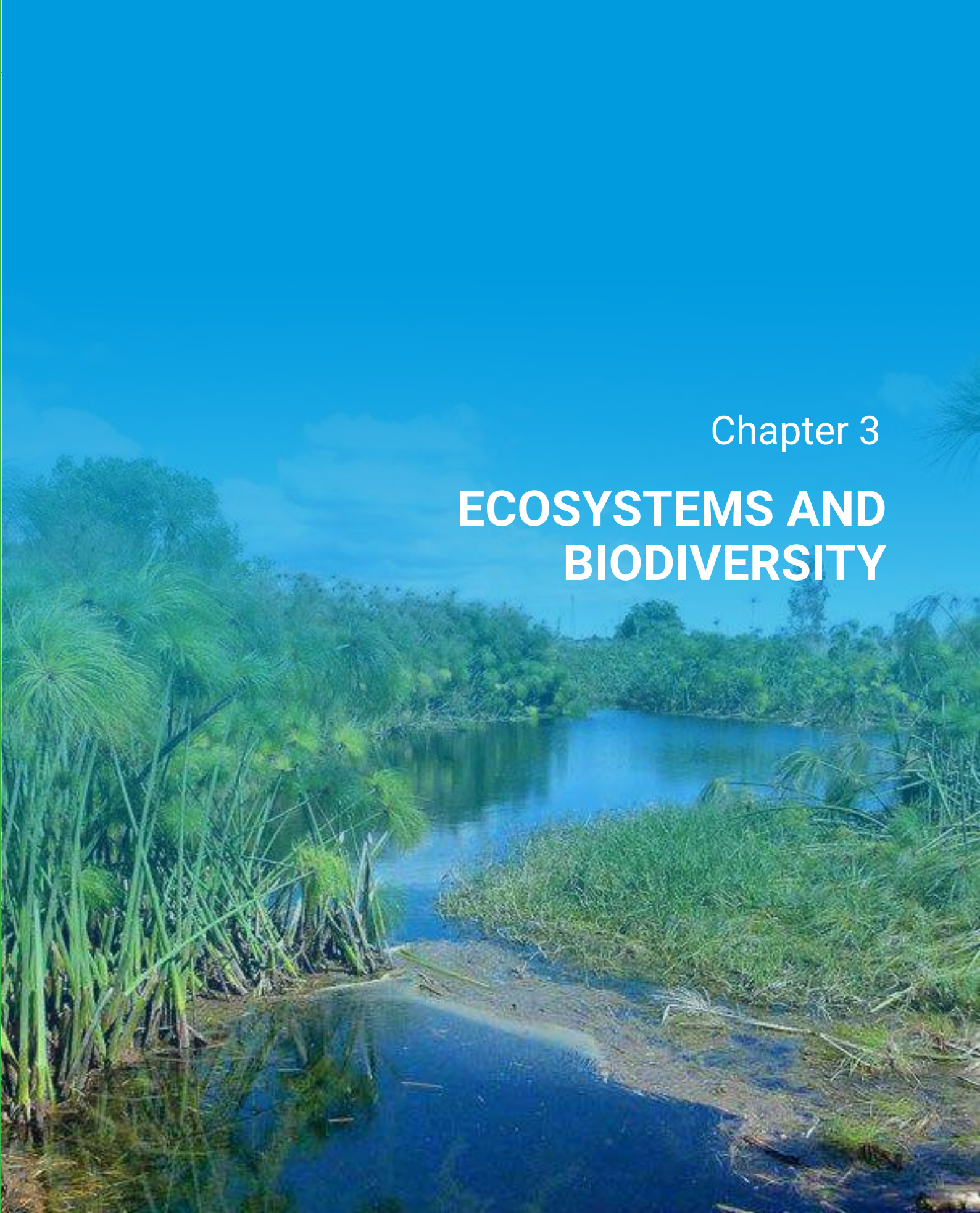
3. **Strengthen Transboundary Governance and Evidence-Based Planning.** Fragmented sectoral approaches must give way to cross-sectoral integration linking agriculture, energy, industry, and environment. Institutionalizing the State of the Basin Report as a core monitoring and decision-support instrument will enable Partner States to track progress, align national plans with regional goals, and mobilize coordinated investment responses. Embedding the SoBR within the LVBC's strategic planning cycle would transform it from a diagnostic publication into a policy engine for adaptive, evidence-driven governance.

2.6.4 Outlook

The Lake Victoria Basin stands at a decisive juncture. Continuing on a business-as-usual path will deepen poverty, inequality, and ecological decline. A different path—anchored in shared investment, strong institutions, and a people-centered green economy—can turn this vital region into a continental model of resilient and inclusive development for the East African Community.

SECTION II

The State of Environment and Natural Resources



Chapter 3

ECOSYSTEMS AND BIODIVERSITY

SUMMARY CHAPTER 3

The Lake Victoria Basin (LVB) is a transboundary ecosystem of immense ecological, social, and economic value. As the cradle of the world's largest tropical lake and the source of the White Nile, its diverse aquatic and terrestrial systems sustain over 45 million people across five nations. Its unique biodiversity, forged through millennia of geological and evolutionary processes, represents a natural heritage of global significance. Chapter 3 analyzes the LVB's ecological assets, the pressures they face, and the governance frameworks established for their conservation and sustainable use.



Major Ecosystems of the LVB

The ecosystems deliver essential services—food, freshwater, hydropower, timber, fuelwood, cultural values, flood buffering, and climate regulation—worth billions of dollars annually.



Conservation Network

Conservation efforts have historically focused more on terrestrial ecosystems than inland waters. Many critical freshwater habitats remain outside the formal conservation network.



Policy, Legal, and Institutional Frameworks

The five basin countries have environmental acts, water policies, and wildlife laws. Implementation is fragmented and inconsistent, undermined by weak enforcement, overlapping mandates, and conflicts between development and conservation priorities.

Major Ecosystems of the LVB

1. The Lake Victoria Basin encompasses an exceptional mosaic of freshwater and terrestrial ecosystems, making it one of Africa's most biodiverse regions. These include the lake's littoral, pelagic, and profundal zones; major rivers such as the Kagera, Mara, Nzoia, Katonga and Yala with their associated wetlands like Yala Swamp, Mabamba Bay, and Nabbajuzi; and satellite lakes including Nabugabo, Kanyaboli, and Ihema that serve as refugia for native species. Montane and lowland forests—Mau, Elgon, Nyungwe–Kibira, Kakamega, and Sango Bay–Minziro—act as vital water towers and biodiversity reservoirs, while the Serengeti–Maasai Mara, Akagera, Lake Mburo and Ruvubu landscapes sustain globally significant wildlife populations.
2. The ecosystems deliver essential services—food, freshwater, hydropower, timber, fuelwood, cultural values, flood buffering, and climate regulation—worth billions of dollars annually. Yet most remain "economically invisible" in planning processes, resulting in unsustainable exploitation.
3. Major threats include habitat destruction, pollution, invasive species, overexploitation of natural resources, human-wildlife conflict, and climate change.
4. Rapid and extensive land use and land cover change—marked by expansion of croplands and urban areas at the expense of forests, wetlands, and rangelands—is transforming the Lake Victoria Basin's ecosystems, degrading water quality, and reducing the Basin's capacity to provide essential ecosystem services

Policy, Legal, and Institutional Frameworks

5. **Regional level**: The East African Community (EAC) provides the overarching framework through the *Protocol for Sustainable Development of the Lake Victoria Basin (2004)*. The Lake Victoria Basin Commission (LVBC) coordinates basin-wide sustainable development, while the Lake Victoria Fisheries Organization (LVFO) oversees fisheries governance. These institutions remain constrained by limited enforcement authority, inadequate budgets, and uneven political commitment.

6. **National level**: The five basin countries have environmental acts, water policies, and wildlife laws. Implementation is fragmented and inconsistent, undermined by weak enforcement, overlapping mandates, and conflicts between development and conservation priorities.

Conservation Network

7. The LVB hosts an extensive conservation network of national parks, forest reserves, Ramsar sites, and community conservation areas. Key examples include Serengeti National Park, Masai Mara Reserve, Nyungwe and Kibira National Parks, and Ramsar wetlands such as Nabugabo and Yala Swamp. These sites face serious challenges including limited funding, inadequate staffing, encroachment, illegal logging, poaching, and agricultural expansion.
8. Conservation efforts have historically focused more on terrestrial ecosystems than inland waters. Many critical freshwater habitats remain outside the formal conservation network.

Regional Management Interventions

9. Several large-scale programs have targeted ecological threats in the basin:
    a. The **Lake Victoria Environmental Management Project (LVEMP I & II)**, funded by the World Bank and GEF, addressed water quality, fisheries, wetlands, and institutional capacity.
    b. Integrated Catchment Management programs, led by LVBC and national partners, promoted soil conservation, reforestation, and pollution control, with visible but localized benefits.
    c. The Lake Victoria Water and Sanitation Initiative (LVWATSAN I & II) implemented by the EAC with support from UN-Habitat and the African Development Bank, invested over US$100 million in improving urban water supply, sanitation, and waste management in 25 secondary towns, contributing to reduced pollution loads into the lake.

    Despite these initiatives, the basin's ecological health continues to decline, underscoring the need for stronger reforms, sustained financing, and effective enforcement.
10. Invasive species illustrate ecological risks: (1) **Water hyacinth** (*Eichhornia crassipes*) spread explosively in the 1990s, disrupting transport, hydropower, and fisheries. Biological control and mechanical clearance reduced its dominance, but resurgence remains likely in nutrient-rich waters; (2) **Nile perch** (*Lates niloticus*), introduced in the 1950s–60s, created a lucrative export fishery but caused one of the most severe vertebrate extinctions in modern times, wiping out hundreds of endemic cichlids and altering the food web. Both cases highlight the long-term socio-economic and ecological costs of poorly regulated species introductions and the need for continuous regional vigilance.

Strategic Recommendations

a. The following strategic priorities are proposed to safeguard the Lake Victoria Basin's biodiversity and natural capital while securing s**ocio-economic benefits for Partner States:**

b. Strengthen governance: Harmonize regulations, empower regional institutions, enforce compliance

c. Scale up ecosystem restoration: Protect water towers, wetlands, and riparian zones

d. Invest in sanitation and pollution control

e. Empower communities: Support co-management systems and alternative livelihoods

f. Bridge knowledge gaps: Re-establish monitoring networks and data-sharing platforms

g. Integrate natural capital into planning: Recognize ecosystem services in national accounts

h. Promote regional cooperation: Foster basin-wide solidarity and joint investment



Figure 3-1. A hippo in Lake Mburo National Park, Uganda.



Figure 3-2. A Papyrus wetland – the most common wetland types in the Lake Victoria Basin.

Key State Indicators – Environment and Natural Resources (2025)

Strategic & Thematic Areas	Indicator / Metric	Value / Range (2025)
E1 Catchment condition		
E1.1 Erosion risk	Area with very low erosion risk	1.8 % of catchment
	Area with low erosion risk	16.4% of catchment
	Area with moderate erosion risk	23.7 % of catchment
	Area with high erosion risk	42.6% of catchment
	Area with very high erosion risk	15.5 % of catchment
E1.2 Land use and land cover change	Rangelands	42.4 % (2017) → 34.0 % (2024) (−8.4 %)
	Water bodies	26.0 % →26.1 % (+0.1 %)
	Tree cover	9.0 % → 11.9 % (+2.9 %)
	Cropland	17.9 % →20.6 % (+2.7 %)
	Built-up areas	4.2 % → 6.9 % (+2.7 %)
	Flooded vegetation	0.3 % → 0.4 % (+0.1 %)
E1.3 Forest cover change	Annual rate of forest cover change	0.3–3.3 % per year
E2 Agriculture		
E2.1 Type and extent of agriculture	Share of terrestrial catchment under cropland	~54 %
E2.2 Agricultural land use sustainability	Status of sustainability assessment methodology	Methodology requires improvement
E3 Terrestrial and aquatic biodiversity conservation and ecosystems		
E3.1 Wetland integrity	Share of LVB catchment under wetlands	~9.8 %
	Long-term wetland area change	~33 % decline (1980s–2020s)
E3.2 Conservation and protected areas	Area under protection	3,659,143 ha
	Share of total basin area protected	~18.9 %
E3.3 Fish diversity, stocks and abundance	Cichlid species remaining	~200–300 species
	Total fish catch	~1.14 million tonnes per year (2021)
	Nile perch	~53 % of catch
	Dagaa	~23.2 % of catch
	Nile tilapia	~7.2 % of catch
	Haplochromines	~1.7 % of catch
	Other species (incl. catfishes)	~14.8 % of catch
E3.4 Invasive aquatic weeds and floating masses	Extent of invasive aquatic weeds	Low coverage
E3.5 Threats and challenges to wildlife	Freshwater species assessed	651 species
	Endemic freshwater species	204 species
	Threatened freshwater species	~76 %

3.1 Significance of the LVB's Ecological Assets

This section highlights the ecological, social, and economic importance of the Lake Victoria Basin. It frames the basin as both a global biodiversity hotspot and a regional lifeline, sustaining millions of people through fisheries, water supply, agriculture, and energy. The analysis establishes the basin's ecological heritage and foundational role in human well-being, setting the stage for understanding the stakes of conservation and sustainable management.

3.1.1 Unique Features and Global–Regional Importance of the Lake Victoria Basin

The Lake Victoria Basin is one of the world's most distinctive freshwater ecosystems, formed in a broad, shallow tectonic depression created by crustal down-warping rather than rifting (Johnson et al., 2000). Periodic desiccation and refilling—the latest about 14,600 years ago—set the stage for rapid ecological diversification.

Globally, it is renowned for the extraordinary adaptive radiation of over 500 haplochromine cichlid species, one of the fastest evolutionary events among vertebrates (Seehausen, 1996; Meier et al., 2017). Yet it also symbolizes ecological decline: invasive species, eutrophication, and overfishing have caused one of the largest modern vertebrate mass extinctions, with more than 75% of endemic species now threatened (Kaufman, 1992; Darwall et al., 2018).

Regionally, the basin is East Africa's socio-economic hub, sustaining nearly 50 million people across five countries. It supports the world's second-largest inland fishery, regional hydropower generation, and extensive agriculture, while facing the paradox of wealth amid widespread poverty and unsustainable resource use (Nunan, 2020).



Figure 3-3. A Lake Victoria flameback cichlid (credits: 1fish2fishdartmouth)

3.1.2 Overview of the Chapter's Scope and Objectives

This chapter examines the ecosystems and biodiversity of the LVB, outlining major aquatic and terrestrial systems, key conservation areas, and the ecosystem services they provide. It analyzes main pressures—habitat loss, pollution, invasive species, and climate change—and reviews existing management frameworks, emerging trends, knowledge gaps, and strategic priorities for conservation.

For clarity, the following terms are used throughout:

- **Biodiversity:** The variability among all living organisms, including diversity within species, between species, and of ecosystems (CBD, 1992).
- **Ecosystem:** A dynamic complex of organisms and their environment functioning as a unit (CBD, 1992).
- **Ecoregion:** A large land or water unit defined by distinct natural communities and conditions (Olson et al., 2001).
- **Ecosystem Services:** Benefits people obtain from ecosystems—provisioning, regulating, cultural, and supporting services (MEA, 2005).

3.2 Major Ecosystems of the Lake Victoria Basin

This section provides an overview of the basin's diverse ecosystems, spanning aquatic, riverine, wetland, and terrestrial systems. It describes their unique ecological functions, biodiversity values, and conservation designations, emphasizing how these interconnected habitats form a complex mosaic of global significance. The assessment underscores their role as the ecological backbone of the basin.

3.2.1 Ecoregions of the Lake Victoria Basin

The Lake Victoria Basin encompasses diverse freshwater and terrestrial ecoregions shaped by topography, climate, and biogeographic history, ranging from lake and wetland systems to forests, savannas, bushlands, and montane habitats (Olson et al., 2001; Thieme et al., 2005) (Textbox 3-1).

> "Regionally, the basin is East Africa's socio-economic hub, sustaining nearly 50 million people across five countries. It supports the world's second-largest inland fishery, regional hydropower generation, and extensive agriculture"

Textbox 3-1: Ecoregions of the Lake Victoria Basin: A Mosaic of Global Significance

The Lake Victoria Basin is one of Africa's most ecologically diverse landscapes, where freshwater and terrestrial systems converge to form a unique ecological mosaic. These ecoregions not only anchor the basin's ecological integrity but also provide essential services—fisheries, water, carbon storage, and cultural heritage—that underpin the livelihoods of millions of people across East Africa.

Freshwater Ecoregions:

- **Lake Victoria Basin Freshwater Ecoregion (FEOW ID: 521)** – This ecoregion not only encompasses the Lakes Victoria basin, but extends to the other great lakes in the region - Edward, George, Kyoga, and Kivu. The ecoregion is characterized by lacustrine fauna with cichlid species radiations typical of the Great Lakes bioregion (Thieme et al., 2005).

Terrestrial Ecoregions:

- **Victoria Basin Forest-Savanna Mosaic (AT0721)** – is the dominant terrestrial ecoregion covering approximately 165,800 km² centered north and west of Lake Victoria, characterized by extensive savanna and woodland interspersed with forest patches and papyrus swamps in river lowlands (Burgess et al., 2004; White, 1983)
- **Albertine Rift Montane Forests (AT0101)** - extends along western boundaries in the Kibira-Nyungo montane ecosystem, containing Africa's highest levels of faunal endemism (Plumptre et al., 2007; Plumptre et al., 2003)
- **Southern Acacia-Commiphora Bushlands and Thickets (AT0716)** - occurs in southern portions with tropical climate receiving 600-800mm rainfall and two annual rainy seasons (Olson et al., 2001)

- **Central Zambezian Miombo Woodlands (AT0704)** - one of Africa's largest ecoregions extending into the southern periphery, characterized by miombo woodland as predominant plant community (Campbell, 1996; Frost, 1996)
- **East African Montane Forests and Moorlands** - occur on isolated mountains above 2,000m elevation, with moorlands occupying 3,500-4,500m consisting of grassland adapted to high elevation conditions (Lovett & Wasser, 1993; Hedberg, 1964)
- **Serengeti Volcanic Grasslands (AT0714)** - volcanic ash-enriched grasslands supporting one of Earth's richest wildlife assemblages and the planet's largest remaining unaltered animal migration, classified as 'vulnerable' with area ranging from 17,900-25,000 km² (Bell, 1971).

3.2.2 The Lake Victoria Aquatic Ecosystem

Lake Victoria is the ecological heart of the basin—a vast inland sea whose size and dynamics shape regional climate, biodiversity, and livelihoods.

3.2.2.1 Physical and Limnological Characteristics

Morphometry: Covering 68,800 km², Lake Victoria is the world's largest tropical lake by area but shallow, averaging 40 m in depth (max ≈ 80–84 m) with a volume of 2,424 km³ (Hamilton et al., 2022). Its broad surface and shallow depth enhance wind mixing and nutrient cycling. The 7,142 km shoreline—dotted with gulfs such as Winam and Mwanza and over 985 islands—creates diverse ecological niches (Worthington, 1931).

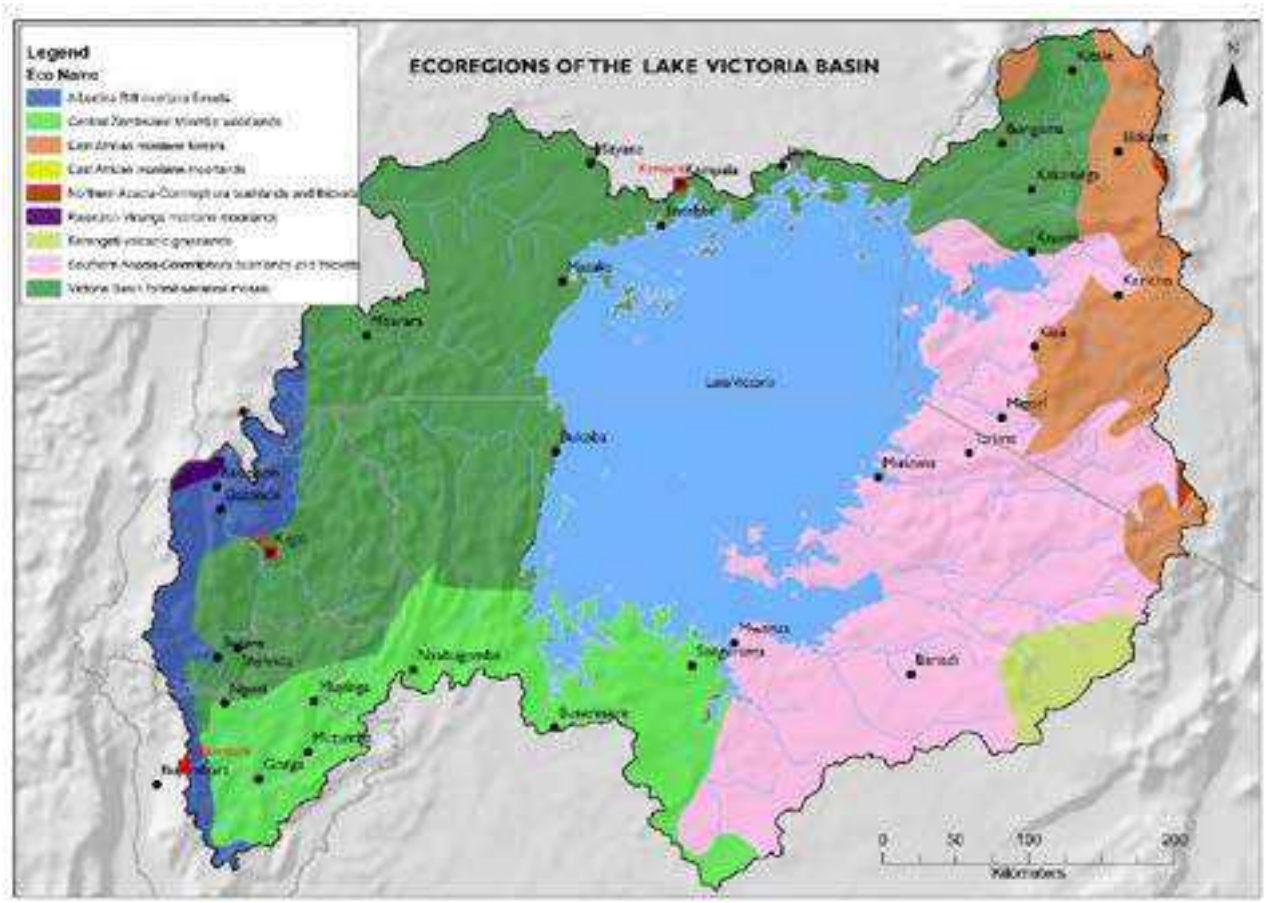


Figure 3-4. *Ecoregions of the Lake Victoria Basin (source:*

Hydrology: With a residence time of about 22 years and flushing time exceeding 120 years (Banyankimbona et al., 2013), the lake retains nutrients and pollutants for decades, intensifying eutrophication and altering its food web.

Ecological zones: The lake comprises three distinct zones:

- **Littoral zone (nearshore):** The most biodiverse habitat, supporting over 90% of fish species in vegetated and rocky nearshore areas. Once rich breeding grounds, it is now degraded by water hyacinth, sedimentation, and habitat loss.
- **Pelagic zone (open water):** Formerly diatom-dominated but now increasingly cyanobacteria-driven due to eutrophication, reducing food-web productivity (Sterner et al., 2020).
- **Profundal zone (deep water):** Below 40 m, oxygen depletion has expanded, creating large "dead zones" and shrinking habitable depth (Silsbe et al., 2006).

While its shallow morphology sustains high productivity and a major inland fishery, it also heightens vulnerability to eutrophication, algal blooms, and hypoxia—risks amplified by warming and stratification (see Chapter 5).



Figure 3-5. *Nearshore area near City of Kisumu on the shores of Lake Victoria*

3.2.2.2 Floral and Faunal Communities

Lake Victoria supports exceptionally rich freshwater biota across open waters, wetlands, and shores, but eutrophication, invasive species, and habitat change have markedly altered community structure.

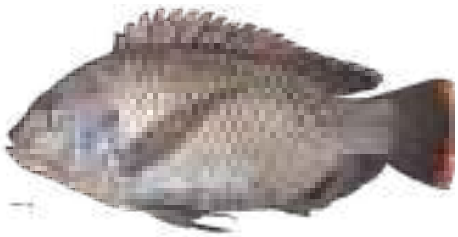
- **Phytoplankton and Zooplankton:** Nutrient enrichment shifted dominance from diatoms to cyanobacteria, driving algal blooms and hypoxia. Zooplankton communities now favor smaller cyclopoids, lowering food quality for fish and altering productivity (Hecky, 1993; Sitoki et al., 2010).
- **Fish Communities:** Once renowned for hosting over 500 endemic cichlids, the lake's native diversity has fundamentally changed. Today, the fishery is dominated by the introduced Nile perch (Lates niloticus) and Nile tilapia (Oreochromis niloticus), alongside the native dagaa (Rastrineobola argentea), reflecting a simplified and less resilient food web (Witte et al., 2007; Njiru et al., 2008) (see Table 3-1; Figure 3-6). This transformation, resulting from deliberate species introductions in the mid-20th century, caused one of the most severe vertebrate mass extinctions in modern times and is detailed further in Section 3.4.3.2.
- **Macrophytes:** The littoral zone supports diverse macrophytes, including submerged species (Vallisneria spiralis, Ceratophyllum demersum), emergent plants (Cyperus papyrus, Phragmites mauritianus), and invasive floaters such as water hyacinth (Eichhornia crassipes). These plants filter nutrients, stabilize shorelines, and provide breeding habitats, but eutrophication and invasive dominance—especially by hyacinth and hippo grass (Vossia cuspidata)—have degraded vegetation, increased turbidity, and reduced habitat quality (Balirwa et al., 2003; Chapman et al., 2018).
- **Invertebrates:** Benthic fauna—comprising chironomid larvae, molluscs, oligochaetes, and the prawn Caridina nilotica—serve as crucial links between detritus and higher trophic levels, supporting nutrient cycling and fish productivity (Mwebaza-Ndawula et al., 2003).
- **Avifauna:** Over 350 bird species depend on Lake Victoria's wetlands, including fish-eating species such as the African fish eagle (Haliaeetus vocifer), herons, cormorants, and pied kingfisher (Ceryle rudis), which have thrived under altered fish communities. The basin also supports wetland specialists such as the Vulnerable shoebill (Balaeniceps rex) and papyrus-endemic passerines like the papyrus gonolek, which serve as indicators of ecosystem health but remain highly vulnerable to wetland degradation and habitat loss (Bennun & Njoroge, 1999; BirdLife International, 2020).
- **Reptiles and Mammals:** The lake supports the Nile crocodile (Crocodylus niloticus), Nile monitor (Varanus niloticus), several turtle species, including the endemic Williams' mud turtle (Pelusios williamsi), and wetland mammals such as hippos and sitatunga (Tragelaphus spekii). These species are key to ecosystem balance but face habitat loss and hunting pressures (Branch, 2008).

Table 3-1. Key Fish Species of Lake Victoria

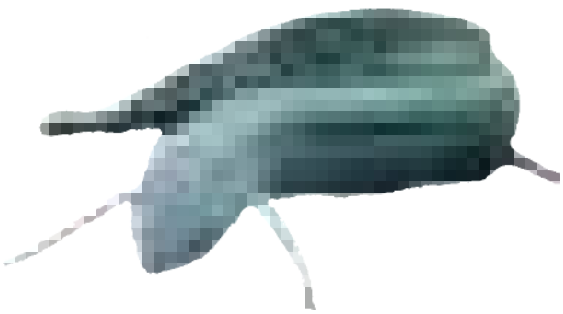
Common Name(s)	Scientific Name	Status in Lake	Historical Abundance (pre-1960)	Current Commercial Importance	IUCN Red List Status (Global)
Nile Perch	*Lates niloticus*	Introduced	Absent	Extremely High (No. 1)	Least Concern
Nile Tilapia	*Oreochromis niloticus*	Introduced	Absent	High	Least Concern
Silver Cyprinid (Dagaa/Mukene)	*Rastrineobola argentea*	Native	Moderate	High (No. 2)	Least Concern
Singida Tilapia (Ngege)	*Oreochromis esculentus*	Native (Endemic)	High (Dominant)	Negligible (Extirpated)	Critically Endangered
Victoria Tilapia	*Oreochromis variabilis*	Native (Endemic)	High	Very Low	Critically Endangered
Marbled Lungfish	*Protopterus aethiopicus*	Native	Common	Low (Local)	Least Concern
African Sharptooth Catfish	*Clarias gariepinus*	Native	Common	Low (Local)	Least Concern
Semutundu	*Bagrus docmak*	Native	Common	Low (Local)	Least Concern
Elephant-snout Fish	*Mormyrus kannume*	Native	Common	Very Low	Not Evaluated
Ripon Barbel	*Labeobarbus altianalis*	Native	Common	Very Low	Least Concern
Silver Butter Catfish	*Schilbe intermedius*	Native	Common	Very Low	Least Concern



Singida Tilapia, Ngege (Oreochromis esculentus)



Victoria Tilapia (Oreochromis variabilis)



Marbled lungfish (*Protopterus authiopicus*)



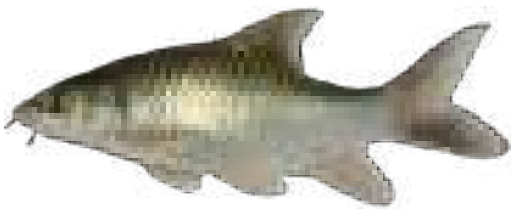
African Sharptooth Catfish (*Claria gariepinus*)



Semutundu (*Bagrus docmak*)



Elepant-snout fish (*Mormyrus kannume*)



Ripon Barbel (*Labeobarbus altianalis*)



Silver Butter Catfish (*Schilbe intermedius*)

Figure 3-6. *Some of the common fish species of Lake Victoria (Source: Wikipedia commons)*

3.2.3 Satellite Lakes of Lake Victoria

Scattered across the basin are over 50 smaller water bodies disproportionately important for biodiversity. These lakes provide refuges for haplochromine cichlids and other native fish that disappeared from Lake Victoria due to Nile perch predation (Chapman et al., 1996). Their isolation and reduced predation pressures allow endemic species to persist and evolve.

- **Lake Nabugabo (Uganda):** Separated from Lake Victoria by a sandbar about 5,000 years ago, Nabugabo and its fringing wetlands (e.g., Lwamunda Swamp) remain free of Nile perch. The system supports five endemic haplochromine cichlids and the critically endangered Singida tilapia. Designated both a Ramsar Site and Important Bird Area, it also hosts threatened birds such as the Shoebill, Papyrus Gonolek, and Blue Swallow.
- **Lake Kanyaboli (Kenya):** Situated in the Yala Swamp complex, Kenya's largest oxbow lake provides a vital refuge for native fish—including endangered tilapias, mudfish, and haplochromines—once common in Lake Victoria. Dense papyrus maintains water quality and habitat complexity, supporting threatened birds like the Papyrus Gonolek and mammals such as sitatunga and otters.
- **Lake Ihema (Rwanda):** Within Akagera National Park, Ihema is surrounded by papyrus swamps, savannah, and woodland that sustain diverse wildlife, including one of East Africa's largest hippo populations, crocodiles, elephants, buffaloes, and over 550 bird species including the Shoebill.

> "Riverine vegetation is diverse and stratified. Gallery forests, particularly along the Kagera floodplain, support Guineo-Congolian species, while adjoining wetlands are dominated by extensive papyrus swamps—among the largest in East Africa."

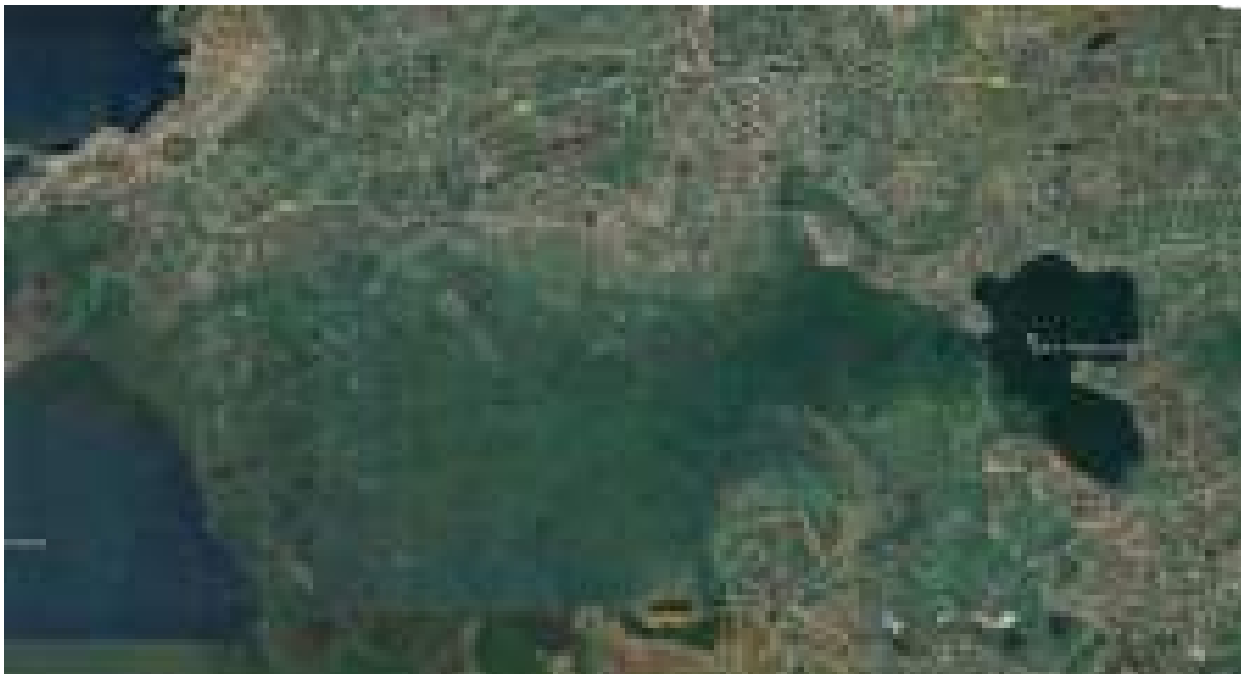


Figure 3-7. *Google Earth image of Lake Kanyaboli in the delta of the Yala River, Kenya*

3.2.4 Riverine Ecosystems

The basin's major rivers—Kagera, Mara, Nzoia, Grumeti, and Yala—form vital ecological arteries that sustain diverse habitats and high biodiversity (Masese et al., 2020). Although rainfall supplies most lake water, rivers contribute 14–20% of inflows and transport much of the sediment and nutrient load (Banyankimbona et al., 2013). The Kagera is the largest tributary, complemented by several key rivers from Kenya, Tanzania, and Uganda.

Riparian and Aquatic Flora

Riverine vegetation is diverse and stratified. Gallery forests, particularly along the Kagera floodplain, support Guineo-Congolian species, while adjoining wetlands are dominated by extensive papyrus swamps—among the largest in East Africa. These wetlands create specialized, oxygen-poor habitats that support distinct biotic communities. Seasonal floodplains sustain rich grasslands used for grazing.

Aquatic and Riparian Fauna

- **Fish:** Rivers once supported abundant Labeo, Barbus, and Brycinus species (Balirwa et al., 2003). The basin remains a global cichlid diversity center, with rivers and satellite lakes serving as refugia. The Kagera alone hosts at least 15 undescribed endemic haplochromines, while the critically endangered Ningu (Labeo victorianus) is basin-endemic.
- **Amphibians and Reptiles:** Wetlands host at least 31 amphibian species and large reptiles such as the Nile crocodile—often exceeding 5 m in the Mara and Grumeti—and the Nile monitor.
- **Birds and Mammals:** River corridors support over 470 bird species, including about 60 raptors. The hippopotamus acts as a keystone species, transferring nutrients from land to water and fueling aquatic food webs (Dutton et al., 2020). The Mara River is globally renowned for the annual crossings of over a million wildebeest and zebra during the Great Migration **(Textbox 3-2).**

Text Box 3-2: The Mara River: Lifeblood of the Great Migration

The Mara River is the only perennial river in the Serengeti ecosystem, providing critical water that allows over 1.5 million wildebeest, zebra, and gazelles to survive the dry season (July to October) by accessing fresh pastures of the Maasai Mara. The dramatic river crossings are the climax of this annual cycle, where herds face immense predation pressure from Nile crocodiles. As the only perennial water source, it also supports large hippo pods and some of Africa's largest crocodiles, making it essential for wildlife survival and global tourism value (Miyagi et al., 2012).



Wildebeest crossing the Mara River (source:)

3.2.5 Wetland Ecosystems

The Lake Victoria Basin hosts some of East Africa's most extensive wetlands, which are essential for both ecological health and human well-being (IUCN, 2018). These wetlands are predominantly permanent papyrus *(Cyperus papyrus)* swamps, forming some of the region's largest stands. Among the most notable are Yala Swamp in Kenya, the basin's largest papyrus wetland supporting nutrient retention, fish breeding, and biodiversity; Mabamba Bay in Uganda, a Ramsar site globally recognized for its intact papyrus and threatened bird species such as the Shoebill; and the Kagera and Mara floodplains, which regulate river flows, sustain fisheries and agriculture, and maintain downstream water quality.

Ecological Roles and Functions

The LVB wetlands, whether fringing the lake or lining river valleys, act as natural treatment systems that trap sediments and absorb nutrients, protecting the lake from siltation and eutrophication (Kiwango et al., 2012). They also buffer hydrological extremes by absorbing storm runoff and sustaining base flows during dry periods. Their peat-rich soils sequester large amounts of carbon, contributing to climate change mitigation, though drainage and conversion are eroding these functions (Chapman et al., 2001).

Biodiversity and Conservation Significance

The LVB wetlands are biodiversity hotspots supporting numerous threatened and endemic species. They serve as vital breeding grounds for

fish and as refugia for haplochromine cichlids that disappeared from the main lake following Nile perch introduction. Characteristic fauna highlight their conservation value:

Specialist fauna highlight the conservation importance of these ecosystems.

- The **Shoebill** *(Balaeniceps rex)*: A Vulnerable species dependent on large papyrus marshes; Mabamba Bay supports one of its most important regional populations.
- The **Sitatunga** *(Tragelaphus spekei)*: A semi-aquatic antelope uniquely adapted to swamp conditions, threatened by habitat loss and hunting.
- The **Papyrus Gonolek** *(Laniarius mufumbiri):* A near-threatened, papyrus-endemic bird serving as a sensitive indicator of wetland integrity.



Figure 3-8. *A shoebill stork in Mabamba Bay*



Figure 3-9. The Papyrus gonolek (Laniarius mufubiri)



Figure 3-10. Sitatunga antelopes

Featured Ecosystem: Yala Swamp Complex (Kenya)

Covering about 17,500 ha at the mouths of the Yala and Nzoia rivers, Yala Swamp is Kenya's largest freshwater wetland and a key ecological refuge in the Lake Victoria Basin. It includes three satellite lakes—Kanyaboli, Sare, and Namboyo—that shelter endangered cichlids and other native fish. Designated both a Key Biodiversity Area and an Important Bird Area, Yala supports diverse livelihoods through fishing, papyrus harvesting, and small-scale rice and sugarcane farming. However, expanding land reclamation and large-scale agriculture are rapidly degrading its ecological integrity.

Featured Ecosystem: Nabbajuzi Wetland System (Uganda)

Nabbajuzi Wetland, a Ramsar site and globally recognized Important Bird Area in Masaka District, is dominated by papyrus interspersed with *Miscanthus* stands. It provides habitat for the Shoebill, sitatunga, and several papyrus-endemic birds, and serves as an important breeding ground for mudfish and lungfish critical to local fisheries. Beyond its biodiversity value, Nabbajuzi supplies piped water to nearly half a million people in Masaka and holds deep cultural importance within the Buganda Kingdom.



Figure 3-11. Yala swamp where Yala River discharges into Lake Victoria.

3.2.6 Montane Forest Ecosystems: The Basin's Water Towers

High-altitude forests surrounding the Lake Victoria Basin form vital ecological anchors and water catchments that regulate river flows, stabilize soils, and sustain the basin's hydrological balance. These Afromontane ecosystems are globally recognized biodiversity hotspots supporting numerous rare and endemic species.

Eastern Highlands (Kenya)

The eastern escarpment of the Rift Valley hosts key montane forest complexes that feed the basin's main rivers. The Mau Forest Complex—East Africa's largest indigenous montane forest—is the principal water tower for rivers flowing into the eastern part of Lake Victoria (the Mara, Nyando and Sondu Miriu). Its high-canopy vegetation, dominated by *Juniperus procera, Prunus africana,Podocarpus latifolius,* and *Olea capensis*, provides critical watershed protection and carbon storage. It hosts critically endangered species such as the Mountain Bongo antelope, the African Golden Cat, and the Yellow-backed Duiker. It is also home to elephants, leopards, and giant forest hogs. The Cherangany Hills, another major catchment for the Nzoia River, harbor over 1,200 plant species, including several endemics. Mount Elgon, an extinct volcano on the Kenya–Uganda border, functions as a transboundary water tower and biodiversity stronghold, home to unique species such as the Elgon Francolin and the critically endangered Du Toit's Torrent Frog *(Arthroleptides dutoiti).*

Western Highlands (Albertine Rift and Rwenzori-Virunga Ecosystem)

The western highlands, part of the Albertine Rift, form one of Africa's most ecologically diverse mountain systems. Extending along the Congo–Nile Divide, these montane forests—including the Nyungwe–Kibira, Volcanoes–Virunga–Mgahinga, and Gishwati–Mukura landscapes—supply the Kagera River headwaters, regulate climate, and support exceptional endemism.

- **Nyungwe–Kibira Ecosystem (Rwanda–Burundi).** Ecosystem (Rwanda–Burundi) represents the region's largest remaining Afromontane forest block and a critical Congo–Nile watershed divide. It supports rich biodiversity, including 14 primate species (notably chimpanzees and Angolan colobus), over 330 bird species, and more than 1,400 plant species, with hundreds of endemics (PFBC-CBFP, 2014; Uwiragiye et al., 2023).



Figure 3-12. Elephants in Mau Forest Complex, Kenya

- **The Volcanoes–Virunga–Mgahinga Ecosystem (Rwanda–Uganda–DRC)** encompasses five major volcanoes and is world-renowned for its mountain gorillas (Gorilla beringei beringei), golden monkeys, and other Albertine Rift endemics. It also regulates headwater flows to the Nyabarongo–Akanyaru–Kagera system but faces growing pressures from settlement and tourism (Masozera & Alavalapati, 2004).
- **The Gishwati–Mukura National Park (Rwanda),** established in 2015 and designated a UNESCO Biosphere Reserve in 2020, is a model of forest landscape restoration. The recovering ecosystem supports chimpanzees, golden monkeys (Cercopithecus mitis kandti), and diverse native flora, while reinforcing watershed protection and climate resilience (CIFOR-ICRAF, 2021).



Figure 3-13. Hikers in Nyungwe Forest National Park, Rwanda

3.2.7 Lowland Forest Ecosystems

At lower elevations, remnants of tropical moist forest represent fragments of the once extensive Guineo–Congolian rainforest. Though highly fragmented, these forests remain critical biodiversity refuges supporting unique flora and fauna.

- **Kakamega Forest (Kenya):** Covering about 178 km², Kakamega Forest is the easternmost remnant of the Guineo–Congolian rainforest and exhibits strong West African floristic affinities. It contains over 380 tree species, including Olea welwitschii (Elgon teak) and Prunus africana (red stinkwood), as well as 60 orchid species, nine of which are endemic. The forest also supports 367 bird species, seven primate species—including De Brazza's monkey—and nearly 500 butterfly species, underscoring its exceptional biological richness.



Figure 3-14. Kakamega Forest, Kenya

- **Mabira Forest (Uganda):** Spanning roughly 30,000 ha—partly within the Lake Victoria Basin—Mabira is Uganda's largest remaining natural forest and a designated Important Bird Area. This semi-evergreen rainforest hosts 312 tree species, 315 bird species, and 23 small mammals, including the endangered Ugandan mangabey ***(Lophocebus ugandae)***. Its high diversity reflects its location at the transition between multiple ecological zones.
- **Sango Bay-Minziro Swamp Forests (Uganda/Tanzania):** Situated along the lower Kagera River, the Sango Bay–Minziro complex forms a distinctive alluvial and swamp forest system combining Guineo–Congolian and Afromontane species. Dominated by *Baikiaea* insignis, these forests are among the most species-rich in the basin. The Minziro Forest Reserve in Tanzania is especially notable for its butterfly diversity, with over 600 recorded species—more than any other forest in Africa.



Figure 3-15. The Kagera River bounded by an extensive papyrus swamp in the Sango Bay area.

3.2.8 Savannas, Woodlands, and Bushlands

Much of the Lake Victoria Basin is a mosaic of savannas, woodlands, and bushlands that sustain vast wildlife populations and underpin pastoral livelihoods.

Victoria Basin Forest–Savanna Mosaic: Extending over about 165,000 km² between 800–1,500 m elevation, this ecoregion is defined by a humid tropical savanna climate with Combretum wooded grasslands, bushlands, and thickets interspersed with seasonally flooded grasslands. It sustains rich biodiversity, including chimpanzees in western forests and recovering elephant populations in protected areas.

Southern Acacia–Commiphora Bushlands and Thickets: The drier southern and eastern basin is dominated by *Acacia* and *Commiphora woodlands* and open grasslands on volcanic soils. This landscape, including the Serengeti plains, hosts the world's largest terrestrial wildlife migration—over a million wildebeest, hundreds of thousands of zebra and gazelle—and supports the highest densities of large predators, including lions, cheetahs, and leopards. It also harbors endemic birds such as the rufous-tailed weaver and Fischer's lovebird.



Figure 3-16. Lions in the Mara National Reserve, Kenya. .

Serengeti Volcanic Grasslands: Spanning ~25,000 km² in northern Tanzania and Kenya, these treeless plains were formed by volcanic ash soils that favor highly productive grasses. They host the iconic 1,000 km annual migration and Africa's highest predator densities, including 4,000 lions, 1,000 leopards, 225 cheetahs, and 3,500 hyenas. The plains also harbor black rhinos and over 500 bird species.

Central Zambezian Miombo Woodlands: In the southwest, mainly in western Tanzania, the landscape transitions into Miombo woodland, Africa's most extensive tropical seasonal woodland. Dominated by *Brachystegia*, *Julbernardia*, and *Isoberlinia*, these semi-deciduous forests are adapted to infertile soils, long dry seasons, and fire. Miombo sustains elephants, buffaloes, sable and roan antelopes, and large carnivores. Increasingly, these woodlands face pressure from shifting cultivation and charcoal production.

3.3 Ecosystem Services and Socio-Economic Value

This section examines the goods and services that the Lake Victoria Basin's ecosystems generate for society and the economy. Using the Millennium Ecosystem Assessment framework, it assesses provisioning, regulating, cultural, and supporting services, quantifies their economic contributions, and highlights the hidden costs of degradation. The analysis demonstrates the direct link between ecosystem integrity and regional development.

The ecosystems of the Lake Victoria Basin provide a continuous flow of goods and services that sustain livelihoods, drive national economies, and underpin regional development. Within the Millennium Ecosystem Assessment framework, these benefits are categorized into provisioning, regulating, cultural, and supporting services. Together, they directly sustain over 45 million people and indirectly support key economic sectors in all five Partner States (Nyamweya et al., 2022). Effective ecosystem management is therefore both an environmental and socio-economic imperative.

3.3.1 Provisioning Services: The Basin's Natural Capital

Provisioning services—food, water, energy, and raw materials—form the foundation of the basin's natural capital and are central to its economic productivity.

3.3.1.1 The Lake Victoria Fishery

Lake Victoria's fishery, the world's second-largest freshwater fishery, supports more than 200,000 fishers and an estimated four million people through processing, transport, and trade. Fish remains the most affordable source of protein for lakeshore communities. Artisanal fisheries, particularly of dagaa (Rastrineobola argentea) and tilapia, provide vital employment and income in rural areas.

Significant potential exists to increase value addition. By-products from Nile perch processing—frames, skins, and viscera—are underutilized despite high market value; fish maws alone can fetch premium prices on global markets (Nyamweya et al., 2022). Developing these value chains could substantially raise community incomes.

Yet the fishery's success masks deep ecological costs. The introduction of Nile perch led to the extinction of over 200 endemic cichlids and disrupted ecosystem balance, contributing to eutrophication and algal blooms. The modern fishery thus illustrates the trade-off between short-term economic gains and long-term ecological stability.



Figure 3-17. Mukene (Dagaa) on sale in a Ugandan market

3.3.1.2 Freshwater Resources

Lake Victoria supplies freshwater to major urban centers—Kampala, Kisumu, and Mwanza—serving at least five million people, while also supporting agriculture, livestock, and industry. Agriculture remains the main livelihood for over 70% of the basin's population, with key crops such as maize, sugar, tea, and coffee relying on its water systems.

Hydropower further underscores the basin's strategic role: the Victoria Nile outflow sustains Uganda's Nalubaale and Kiira power stations, which generate about 380 MW and are crucial for regional energy security. Stable lake levels are therefore essential for both water and power supply, linking environmental governance directly to economic resilience.

3.3.1.3 Biological Raw Materials

Forests and wetlands provide indispensable raw materials for domestic and commercial use. About 80% of households depend on woodfuel and charcoal, which supply around 90% of household cooking energy (Mango et al., 2011). Forests also provide timber, poles, and non-timber products that support local industries.

Wetlands yield papyrus used in handicrafts such as mats and baskets, offering income to artisanal households and potential for bioenergy production. The basin is also rich in medicinal plants that support traditional healthcare systems and rural livelihoods through small-scale trade (WHO, 2019).

3.3.2 Regulating Services: Maintaining Environmental Stability

Regulating services, though less visible than provisioning ones, are essential to the Lake Victoria Basin's resilience—maintaining water quality, stabilizing landscapes, and moderating climate.

3.3.2.1 Water Purification and Nutrient Cycling

Wetlands, especially papyrus swamps, function as natural filters that trap sediments, absorb excess nutrients, and remove pollutants from runoff before reaching the lake. Intact wetlands can retain over 40% of incoming nutrients, reducing eutrophication and treatment costs. Papyrus harvesting also aids nutrient removal and supports sustainable wetland use.

3.3.2.2 Flood and Erosion Control

The basin's montane forests—such as the Mau Montane forests such as the Mau Complex and Mount Elgon absorb rainfall, recharge groundwater, and prevent erosion and landslides. When degraded, runoff and sedimentation intensify, destabilizing river flows. Fringing wetlands further buffer floods and trap sediments, lowering soil loss and protecting downstream habitats. Across the basin, erosion is estimated to cost over US$10 million annually (Nyamweya et al., 2022).

3.3.2.3 Climate Regulation and Carbon Sequestration

The lake moderates regional rainfall and temperature, while forests and wetlands act as major carbon sinks. Papyrus wetlands sequester roughly 0.5 kg of carbon per square meter annually, with deep peat layers storing hundreds of tonnes per hectare. Forests across the Ugandan basin alone hold over 600,000 tonnes of carbon stock, underscoring the basin's importance for climate mitigation.

3.3.2.4 The Challenge of "Economic Invisibility"

Despite their immense value, regulating services remain largely absent from economic decision-making. Land-use changes often prioritize short-term gains while externalizing long-term costs such as water treatment, flood control, and health impacts from pollution. Incorporating ecosystem service valuation—through payments for ecosystem services, natural capital accounting, and stronger land-use enforcement—is essential for sustainable development.

3.3.3 Cultural and Supporting Services: The Intangible and Foundational Values

Cultural services provide non-material benefits that enrich human life and identity, while supporting services sustain the ecological processes that underpin all others. Together, they connect people to nature and maintain the basin's long-term productivity.

3.3.3.1 Cultural Heritage, Recreation, and Tourism

The Lake Victoria Basin's scenic landscapes, rich wildlife, and enduring cultural traditions offer diverse opportunities for recreation, spirituality, and tourism. Activities such as sport fishing, boating, birdwatching, and ecotourism attract regional and international visitors, making tourism a growing contributor to local and national economies (Nyamweya et al., 2022). The basin is also a centre for learning, education, and scientific research.

The lake and its physical and ecological features are deeply embedded in the belief systems, identities, and social structures of communities in Kenya, Uganda, and Tanzania. This heritage is expressed through ancient stone settlements such as the UNESCO-listed Thimlich Ohinga, which reflects the social sophistication of early societies. It is also expressed through extensive rock art sites at Kakapel, Dolwe, and Abindu, and sacred hills (such as Got Ramogi and Riat), forests, waterfalls and groves used for ceremonies and ancestral worship, The lake's islands hold particular spiritual importance, notably the Bugala and Musambwa Islands, which are associated with powerful spirits, traditional healers, strict customary rules, and long-standing ritual practices that also support biodiversity conservation. Many of these sites remain active today, symbolizing enduring connections between people and nature that reinforce conservation values. Protecting this cultural and spiritual heritage is essential for preserving identity, strengthening community stewardship, and sustaining the holistic relationship between people and the Lake Victoria ecosystem.

3.3.3.2 Biodiversity and Foundational Services

Supporting services—such as soil formation, nutrient cycling, and biodiversity maintenance—form the ecological foundation of the basin's productivity. Lake Victoria is globally renowned for the rapid adaptive radiation of haplochromine cichlids, with over 500 endemic species evolving in about 15,000 years, making it a "living laboratory" for evolutionary science.

The basin also harbors wild relatives of major crops and resilient indigenous livestock breeds, providing vital genetic resources for food and livelihood security under changing climates. In addition, regional research institutions—KMFRI, NaFIRRI, and TAFIRI—serve as centers of scientific innovation, supporting evidence-based management of fisheries, biodiversity, and climate challenges.



Figure 3-18. *Lutembe Bay Ramsar Site near Entebbe, Uganda*

3.3.4 Economic Value of Key Ecosystem Services

Ecosystem services in the Lake Victoria Basin generate billions of dollars annually. The table below summarizes estimated economic values, highlighting both tangible and intangible benefits of the basin's natural capital.

Table 3-2. Estimated Annual Economic Value of Key Ecosystem Services in the LVB

Ecosystem Service	Economic Activity / Estimate	Beneficiaries / Notes	Source(s)
Provisioning			
Lake Victoria Fishery (total landed value)	~US$1.1 billion (2021, 1.48 MT)	3+ million people employed; ~8m rely on fish protein	Nyamweya et al., 2023
Nile Perch Exports	~US$150–250 million	Export earnings, GDP contributions (2–3%)	LVFO, 2018; Nyamweya et al., 2022
Dagaa Fishery	~US$135 million (2014)	Low-value but high-volume (55% catch)	LVFO, 2018
Hydropower Generation	~380–580 MW capacity (≈US$190m/yr at $0.05/kWh)	Uganda's main electricity supply	World Bank, 2018; AfDB, 2021
Freshwater Supply	>5 million urban residents (Kampala, Kisumu, Mwanza, etc.)	Domestic & industrial use	World Bank, 2018; ACARE, 2021
Regulating			
Erosion Control	~US$10 million (soil loss avoided annually)	Agriculture, water quality	Nyamweya et al., 2022
Carbon Sequestration	~700 tC/ha stored in papyrus wetlands	Global climate regulation	Uganda NCA Report, 2019; WWF, 2001
Cultural*			
Tourism (Uganda, 2011)	US$805 million (foreign visitors)	Jobs, GDP (9%)	UBOS, 2014
Tourism Potential (EAC projection)	US$800 million/yr if fully developed	Regional economies	EALA, 2020
Recreational Value (wetlands, Tanzania)	US$1.04 million/yr (≈US$6,965/ha)	Local communities	Musamba et al., 2011
Cultural Heritage (WTP study, Kenya)	KES 616 million/yr (≈US$5.6m)	Willingness-to-pay for conservation	Mamboleo & Adem, 2022
Supporting			
Agricultural Biodiversity	Wild relatives of sorghum, millet, beans; indigenous livestock	Food security & climate resilience	IUCN, 2019
Medicinal Plants	162 species traded; thousands of kg/year	Traditional healthcare, local trade	Hilonga et al., 2018
Wetland Raw Materials	~US$11,000+/ha NPV (Uganda papyrus swamps)	Craft products, fuel, bioenergy	Sikoyo & Goldman, 2015

**Note*: *Estimate of cultural values include contributions from ecosystems outside Lake Victoria.*

3.4 Major Threats to Ecosystems and Biodiversity

This section analyzes the drivers and pressures undermining the basin's ecological health, including habitat loss, pollution, overexploitation, invasive species, and climate change. It highlights how these threats are interconnected, creating reinforcing cycles of degradation that erode ecosystem resilience and community well-being. The assessment provides the evidence base for urgent and integrated responses.

The Lake Victoria Basin's ecosystems face accelerating degradation from habitat loss, pollution, overexploitation, invasive species, and climate change. Rapid population growth, unplanned urbanization, and poverty intensify these pressures, creating feedback loops that erode ecological integrity and community resilience (FAO, 2019; Nyamweya et al., 2022). Figure 3-19 shows the degradation hotspots in the LVB.

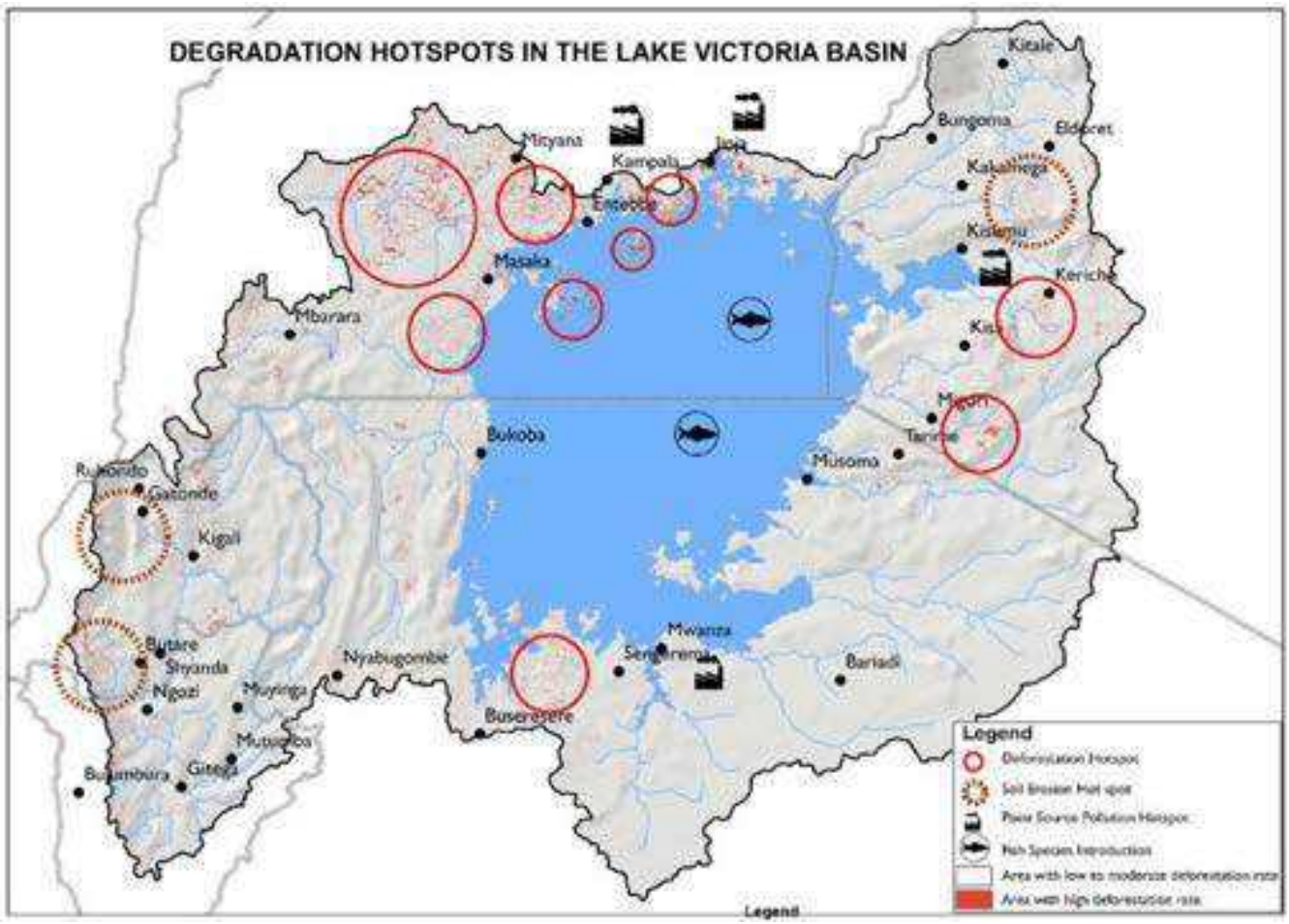


Figure 3-19. *Key degradation hotspots in the Lake Victoria Basin*

3.4.1 Land Use Change and Habitat Degradation

3.4.1.1 Deforestation and Forest Degradation

Land Use and Land Cover (LULC) describe how land is utilized and its physical characteristics—factors that critically influence hydrology, water quality, flood regulation, and ecosystem services.

The basin's catchment has undergone rapid transformation as forests, wetlands, and grasslands give way to farms and urban areas. These changes have disrupted hydrological regimes and heightened flood peaks, while the associated increase in nutrient and sediment loading is a primary driver of water quality degradation (Olang & Fürst, 2011; Nyamweya et al., 2022; Nakkazi et al., 2024), as detailed in Section 3.4.2. Declining vegetation cover has weakened soil retention, water filtration, and climate-regulation functions, trapping many communities in cycles of environmental degradation and poverty (Masese et al., 2025). As shown in Figure 3-19, key hotspots of soil erosion in the LVB include the Nzoia, Yala, Ruvubu and Nyabarongo sub-catchments. Effective LULC management is therefore essential to safeguard water security, ecosystem integrity, and climate resilience (Kiggundu et al., 2023).

3.4.1.2 Short-term (2017-2024) Changes in Land Use and Land Cover

Recent high-resolution satellite data show pronounced land-cover shifts across the basin. In 2017, rangelands dominated (42.4%), followed by water (25.9%), cropland (17.9%), built-up areas (4.2%), and bareland (0.2%). By 2024, rangelands had declined to 34.0%, cropland rose to 20.6%, built-up areas nearly doubled to 6.9%, and water remained stable at 26.1%; bareland fell sharply to 0.006% (Impact Observatory et al., 2024). These changes reflect expansion of cropland, tree cover, and settlements at the expense of natural rangelands. Complementary datasets, such as Global Forest Watch, indicate continued decline of natural forests across the basin (Masese et al., 2025).

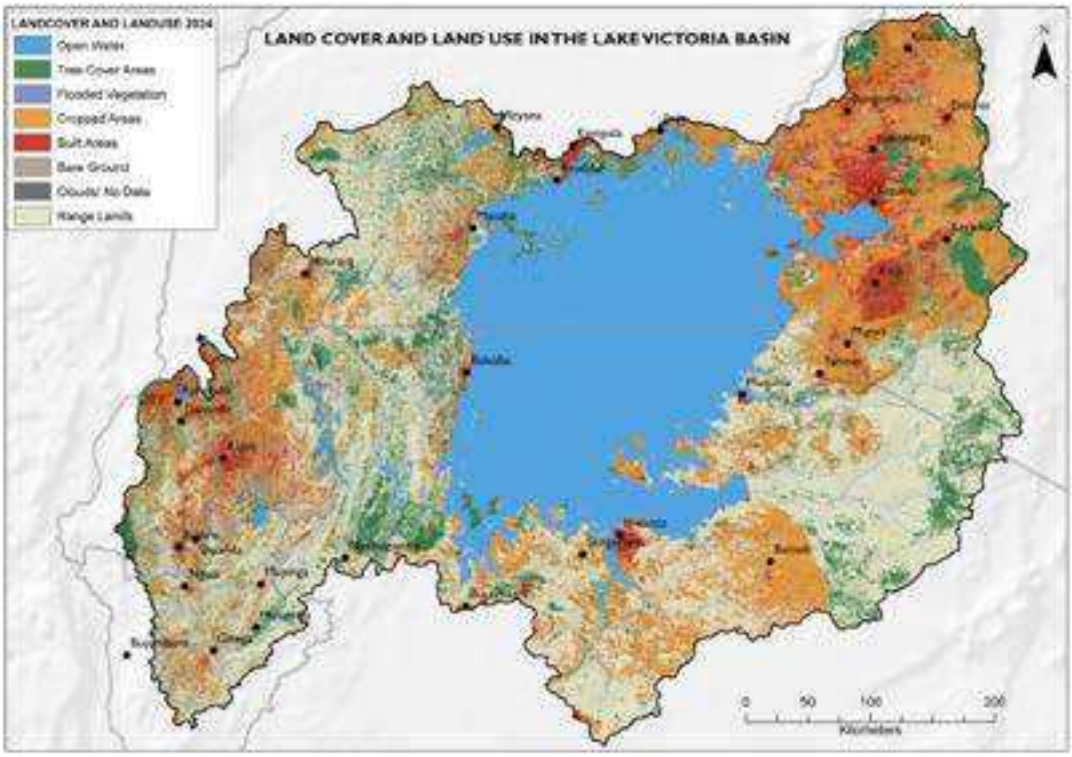


Figure 3-20. *Land Use and Land Cover in the Lake Victoria Basin in 2024 (Impact Observatory et al., 2024),*

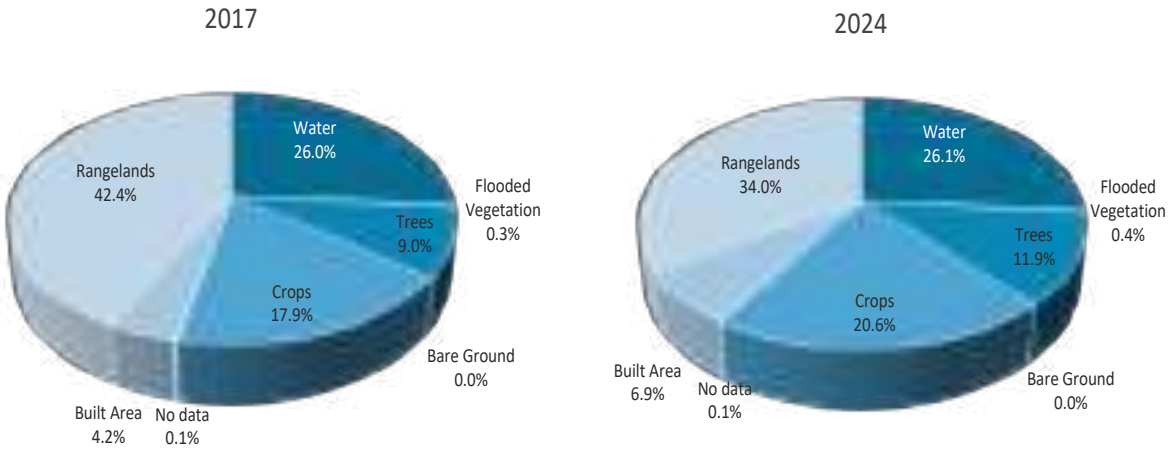


Figure 3-21. *The percentage contribution of land use/land cover classes in Lake Victoria (Impact Observatory et al., 2024),*

3.4.1.3 Key trends

Land-cover changes in the basin mirror continental patterns where most new cropland in sub-Saharan Africa replaces natural vegetation (NASA Earth Observatory, 2022; Potapov et al., 2022). Shifts among rangelands, croplands, and urban areas between 2017 and 2024 reveal accelerating land conversion with serious implications for water resources and ecosystem integrity.

Rangelands in sub-basins such as Mara, Grumeti, and Simiyu remain extensive but are increasingly affected by woody encroachment. Satellite data (2017–2024) show rising tree cover in most sub-basins, driven by overgrazing, altered fire regimes, and climate variability. This transition from open savannas to dense woodland reduces grazing productivity and alters habitat structure (Venter et al., 2018; Atkinson et al., 2022).

Cropland grew from 17.9% to 20.6% between 2017 and 2024, largely replacing rangelands and natural vegetation. The trend aligns with continental evidence that roughly 80% of new farmland originates from forested or shrubland areas (Potapov et al., 2022). In the Lake Victoria Basin, population pressure and food demand drive both intensification and expansion, with agriculture employing about 75% of the labour force (Maitima et al., 2010; Nyamweya et al., 2022).

Built-up areas rose from 4.2% to 6.9% over the same period, continuing decades of rapid growth—up to tenfold since 1985. Cities such as Kampala, Kisumu, and Mwanza are expanding into wetlands and peri-urban farmlands, increasing runoff, pollution, and land competition (Nyamweya et al., 2022).

> “The basin’s catchment has undergone rapid transformation as forests, wetlands, and grasslands give way to farms and urban areas. These changes have disrupted hydrological regimes and heightened flood peaks.”

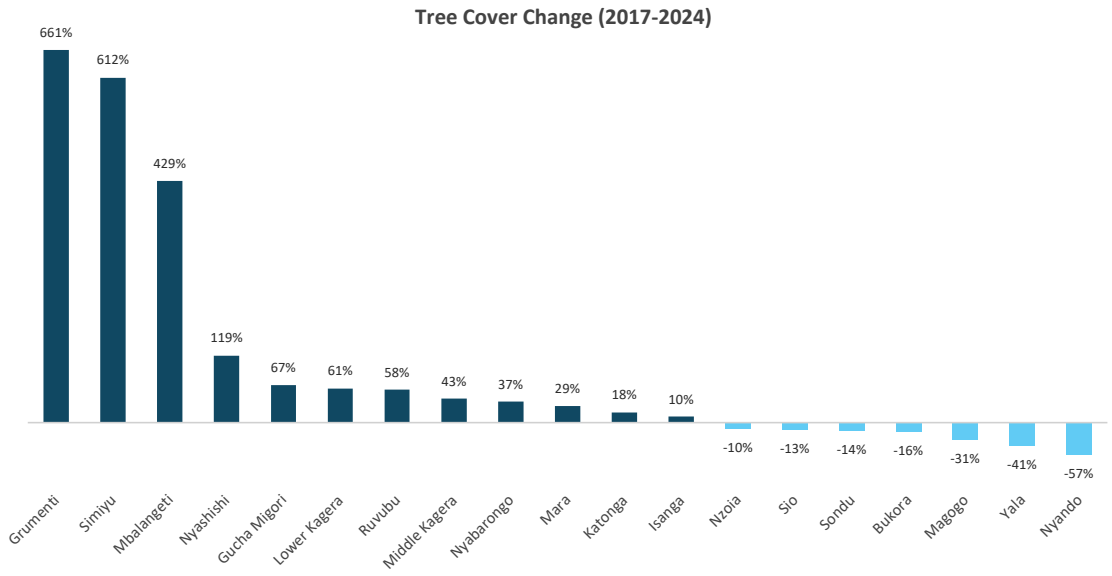


Figure 3-22. *Tree cover change in the sub-basins on Lake Victoria (Impact Observatory et al., 2024),*

3.4.1.4 Major Forms of Habitat Degradation

The LULC trends of agricultural and urban expansion are the primary drivers of habitat loss and degradation across the basin:

- **Deforestation and Forest Degradation:** Over 70% of the basin's original forest cover has been lost. Uganda records the steepest decline—about 3.3% annually between 2000 and 2015—compared to 0.3% in Kenya and 0.8% in Tanzania (Waiswa et al., 2015). Agricultural expansion, timber extraction, and charcoal production are the primary drivers, reinforced by poverty, insecure land tenure, and weak governance. The loss of forested water towers accelerates erosion, sedimentation, and fragmentation of wildlife corridors, reducing habitat connectivity and species viability (Ojoatre et al., 2023).
- **Wetland Drainage and Conversion:** Wetlands, crucial for water purification and biodiversity, have declined by roughly one-third since the 1980s. Agricultural conversion remains the dominant cause, driven by rising land demand and poor enforcement of environmental regulations (IUCN, 2016; IPBES, 2016).
- **Shoreline and Riparian Degradation:** Riparian zones face severe stress from sand and clay mining, which destroys breeding habitats and increases turbidity (Nyamweya et al., 2022). Rapid lakeshore urbanization has hardened surfaces, amplified runoff, and heightened flood risks in ecologically sensitive areas (Mango et al., 2011).

3.4.1.5 Drivers, Future Projections, and Implications

Population growth—with Tanzania's population expected to double in 23 years —is a key driver of LULC change in the Lake Victoria Basin (World Bank, 2023). Urban centers grow even faster, exceeding 6% annually and converting wetlands and farmland to settlements. Weak land governance, insecure tenure, and limited enforcement further promote unsustainable exploitation (Willy et al., 2023). Additional pressures stem from rising demand for food and infrastructure, overgrazing, and climate variability, which together accelerate forest loss and rangeland degradation (Monitor, 2020; Namaganda, 2018).

By 2050, the basin's population may reach 150–180 million, with temperature increases of 1.4–2 °C and 5–16% more rainfall, intensifying droughts and floods (Booij et al., 2019; Alemayehu et al., 2023). Without integrated land and climate management, continued expansion of agriculture and settlements will heighten erosion, deforestation, and water-quality decline.

Accelerated land conversion has already increased runoff, sedimentation, and nutrient loading, which are the key drivers of the eutrophication and algal blooms plaguing the lake (Olang & Fürst, 2011; Masese et al., 2025). Built-up areas have grown more than 300% since 2000, while indigenous forests have shrunk by over 40%, resulting in habitat loss, reduced biodiversity, and weaker carbon-storage capacity (Nakkazi et al., 2024; Nyamweya et al., 2022).

About 80% of rural households depend on forests for energy and food, and over 250,000 smallholders earn most of their income from forest-linked farming (Katusiime & Schütt, 2021; LVBC & GRID-Arendal, 2017). Forest loss and soil erosion threaten agricultural productivity, hydropower reliability, and livelihood security, especially in the Mau and Cherangani water towers (UNEP, 2012). Environmental decline and livelihood stress reinforce cycles of poverty and unsustainable resource use.

3.4.2 Pollution of Aquatic and Terrestrial Systems

Pollution from agricultural runoff, industrial effluents, and domestic waste is the principal cause of water-quality decline in Lake Victoria and its tributaries, posing one of the most serious threats to the lake's ecological integrity.

Eutrophication remains the most severe manifestation of this pollution. Nutrient-rich runoff from intensive agriculture, untreated sewage from rapidly growing cities such as Kampala, Kisumu, and Mwanza, and industrial discharges drive recurrent algal blooms and oxygen depletion. Atmospheric nitrogen from biomass burning adds to the load (Kiwango & Wolanski, 2008). These inputs have fundamentally altered the lake's ecology—reducing water clarity, creating hypoxic "dead zones," and triggering periodic fish kills that disrupt aquatic food webs (IUCN, 2019).

Industrial and mining effluents introduce heavy metals such as mercury, lead, and cadmium, which accumulate in sediments and bioaccumulate through the food chain, posing risks to fish and human health (Lung'ayia et al., 2001).

Solid-waste and plastic pollution are also widespread due to poor waste management in urban and fishing communities. Discarded nets, single-use plastics, and other debris litter shorelines and open water. Microplastics have been found in all sampled sites and in roughly one-fifth of Nile perch and tilapia examined (Biginagwa et al., 2016). These materials degrade habitats, endanger wildlife through ingestion and entanglement, and leach toxic additives into aquatic ecosystems.

3.4.3 Invasive Alien Species

Non-native species have profoundly altered Lake Victoria's ecosystems. The most damaging are aquatic weeds—especially water hyacinth, giant salvinia, and water lettuce—which continue to degrade habitats, fisheries, and livelihoods, while terrestrial invaders such as *Lantana camara* threaten rangelands and croplands.

3.4.3.1 Invasive Aquatic Weeds

Water hyacinth

Introduced to East Africa as an ornamental plant, water hyacinth (Eichhornia crassipes) escaped into the Kagera River in the late 1980s and spread rapidly across the lake during the

1990s (Figure 3-24). Vast mats blocked sunlight, reduced photosynthesis, and created anoxic "dead zones," causing major biodiversity losses and recurring fish kills. Economic impacts were severe: fisheries were obstructed, transport and hydropower intakes (notably at Owen Falls) clogged, and landing sites rendered unusable. Stagnant mats also became breeding grounds for malaria and schistosomiasis vectors. At its 1998 peak, satellite imagery estimated over 17 000 ha infested (Masifwa et al., 2001; Albright et al., 2004).



Figure 3-23. *Water hyacinth in a shoreline area of Lake Victoria*

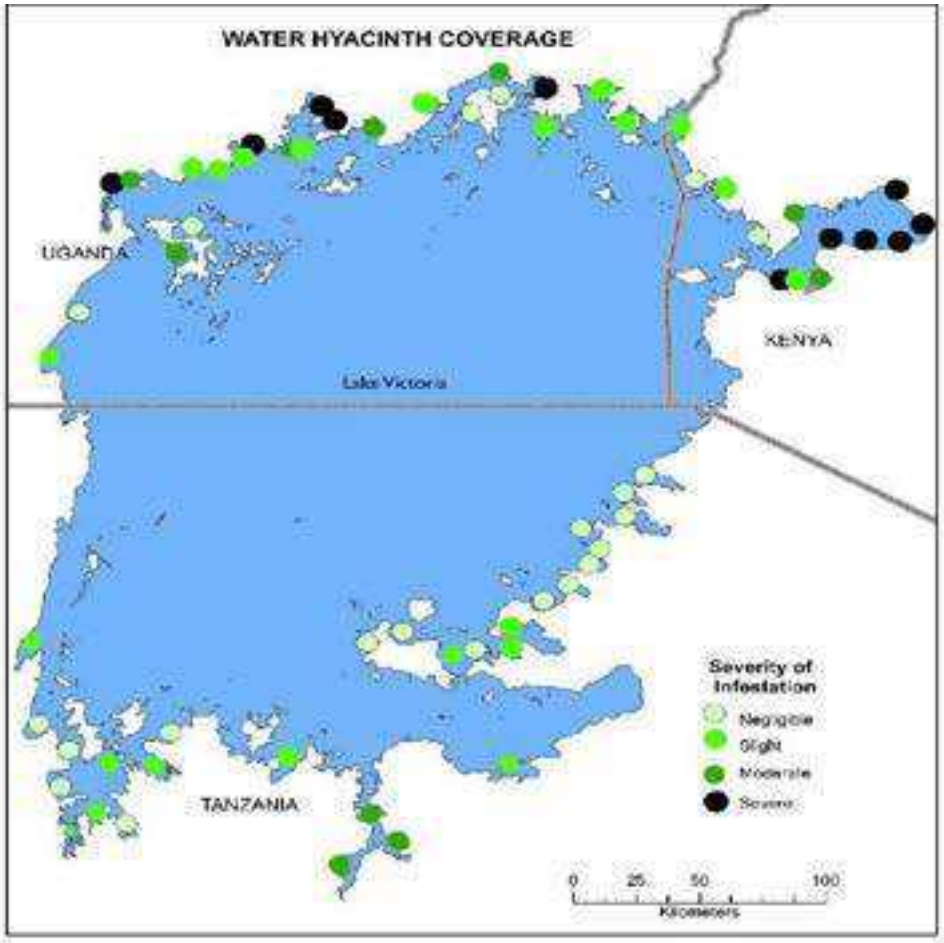


Figure 3-24. *The observed relative severity of water hyacinth infestation as detected by imagery collected between 1994 and 2001 (source: Albright, et al., 2004). Key: Negligible – never more than 0.5% of area of feature visible covered by water hyacinth; Slight – at least one image showing more than 0.5%;Moderate – at least two images showing more than 2% coverage; Severe – at least two images showing more than 7% coverage.*

A coordinated regional response under the Lake Victoria Environmental Management Project (LVEMP), supported by the World Bank and GEF, adopted integrated pest management combining biological, mechanical, and institutional measures. The release of host-specific Neochetina weevils—the primary control—successfully reduced infestations by more than 95 percent between 1998 and 2001, aided by the 1997–1998 El Niño (Masifwa et al., 2001). Mechanical clearance of harbours and intakes complemented biological control, while cross-border monitoring frameworks laid the foundation for ongoing coordination through LVBC (Kateregga & Sterner, 2007). Despite these successes, water hyacinth persists through nutrient enrichment, sheltered bays, and a long-lived seed bank. Major resurgences in 2006, 2018, and 2020 confirm its status as a chronic ecological threat likely to intensify under climate-driven rainfall variability (Villamagna & Murphy, 2010). Long-term suppression depends on sustained biocontrol, basin-wide surveillance, and nutrient-load reduction across the watershed.

Giant salvinia

The giant salvinia *(Salvinia molesta)* (Figure 3-25), a fast-growing invasive fern native to South America, has recently spread into Lake Victoria from the upper Nile system, with key entry and breeding sites identified in the Katonga River Basin. The situation with respect to this weed is increasingly alarming: during the June–July joint lake cruise, scientists from Kenya, Tanzania, and Uganda observed large, mobile mats of giant salvinia in nearshore waters across all three countries, indicating active basin-wide spread. In warm, nutrient-rich waters, salvinia can double its biomass within days, forming dense floating mats up to a metre thick that block light penetration, deplete dissolved oxygen, and severely impede navigation, fisheries, aquaculture, and water abstraction (McFarland et al., 2003; Angima, 2023). Given the species' rapid expansion potential and the region's limited preparedness to manage large-scale infestations, there is a real risk of a recurrence of the extensive aquatic weed coverage experienced in the 1990s. Early Detection and Rapid Response (EDRR) is therefore critical. Priority should be given to building capacity for biological control using the host-specific *Cyrtobagous salviniae* weevil—proven effective in other regions—supplemented by targeted mechanical removal to safeguard critical infrastructure during establishment phases. Basin-wide surveillance and mapping are urgently needed to identify infestation hotspots and support coordinated, transboundary management action, as uncontrolled salvinia invasion represents a disaster waiting to happen for Lake Victoria's ecosystems and livelihoods.



Figure 3-25. *The Giant Salvinia (Salvinia molesta) – an accelerating, high-impact invader.*

Water lettuce

Water lettuce (*Pistia stratiotes*) (Figure 3-26), a long-established pantropical species in the Nile system, once formed extensive mats in sheltered bays but was largely displaced by water hyacinth during the 1990s (CABI, 2014). As hyacinth cover declines, *Pistia* often re-emerges in nutrient-enriched, wind-sheltered areas, creating similar ecological effects—light exclusion, oxygen depletion, and impeded fishing and

transport. Monitoring should track this species as a potential "sleeper" invader, combining mechanical clearance, selective herbicide use, and biological control with the *Neohydronomus affinis* weevil where needed (Center et al., 2002).



Figure 3-26. *The water lettuce (Pistia stratiotes) a common water of the Nile river system.*

Experience with these macrophytes shows that success against one invader can free ecological space for others. A basin-wide strategy must therefore target underlying nutrient enrichment, institutionalise EDRR for all floating weeds, and integrate remote-sensing-based monitoring with rapid field verification. Safeguarding aquaculture zones and hydropower intakes through debris booms, adaptive maintenance, and contingency funding is also essential (Julien et al., 2002; Balirwa et al., 2003).

3.4.3.2 Introduced Fish and Biodiversity Collapse

Nile Perch and Tilapia introductions

Nile Perch: Introduced in the 1950s–1960s, Nile perch (Lates niloticus) (Figure 3-27) transformed both the ecology and economy of Lake Victoria. After decades of scarcity, its population surged, rising from 0.4% of catches in 1975 to 60–80% by the 1990s (Ogutu-Ohwayo, 1990). As an apex predator, it eliminated intermediate species and profoundly restructured the food web. Economically, the fishery generated over US$200 million annually but destroyed subsistence fisheries, drove fuelwood demand for fish processing, and triggered cascading socio-economic impacts (Downing et al., 2014).



Figure 3-27. *Man carrying Nile perch fish.*

Nile Tilapia: Nile tilapia (*Oreochromis niloticus*) (Figure 3-28) expanded gradually, increasing from 2% of catches in 1983 to 21% by 1990, and now dominates tilapiine communities while displacing native *O. esculentus* (Ogutu-Ohwayo, 1990). Its diet shifted from herbivory to omnivory, enabling it to exploit nearshore habitats. Since the 2000s it has supported aquaculture growth, though with challenges including genetic pollution of wild stocks.



Figure 3-28. *The Nile tilapia (Oreochromis niloticus) (credits: the Centre for Aquaculture Technologies).*

Haplochromine Cichlid Radiation and Catastrophic Loss

Lake Victoria's haplochromine cichlids exemplify one of the fastest known vertebrate adaptive radiations, with over 500 endemic species evolving in ~15,000 years following the lake's Pleistocene desiccation (Meier et al., 2017; McGee et al., 2020). This extraordinary diversification was driven by sexual selection, trophic specialization across at least 15 niches, and hybridization between ancestral Nile and Congo lineages that reassembled genetic variation (Brawand et al., 2014). This evolutionary marvel has undergone catastrophic collapse. Haplochromines, which constituted about 80 % of total fish biomass in the 1960s–1970s, declined sharply during the Nile perch boom of the 1980s–1990s (Witte et al., 2000). More than 200 species are now extinct or critically threatened—approximately 40 % of the original diversity (Seehausen et al., 1997). The losses stem from Nile perch predation, eutrophication-driven turbidity that disrupted mate recognition, and extensive habitat degradation. Of 651 assessed freshwater species, 204 are endemic and 76% threatened (Darwall et al., 2018).

Plankton Community Changes

Plankton shifts mirror the wider ecosystem transformation. Historically dominated by diatoms, phytoplankton are now largely cyanobacteria, while zooplankton communities have shifted from large calanoid copepods and cladocerans to small cyclopoids (Sterner et al., 2020). Cladoceran collapse around 1960 was linked to eutrophication and lake level rise. These changes reduced trophic efficiency, as cyanobacteria provide poor nutrition and smaller zooplankton limit energy transfer to fish. Enhanced cyanobacterial decomposition further accelerates oxygen depletion, reinforcing ecosystem degradation.

3.4.3.3 Terrestrial Invasive Species

On land, *Lantana camara* has invaded large areas of degraded woodland and pasture, forming dense thickets that suppress native vegetation, reduce livestock forage by over 50 percent, and cut crop yields by up to half. The economic burden falls most heavily on smallholder and pastoral communities reliant on open rangelands.

3.4.4 Other threats to wildlife

The ecological integrity of the Lake Victoria Basin continues to erode under pressure from overexploitation of resources, human–wildlife conflict, and the intensifying impacts of climate change. Together these threats weaken ecosystem resilience and jeopardize the livelihoods of millions.

Overharvesting of fish, forests, and wetlands remains a major concern. Lake Victoria's fisheries produce about one million tonnes annually, yet unsustainable exploitation has depleted native stocks. The average size of Nile perch has fallen sharply, with nearly 40 percent of large individuals caught before maturity, undermining replenishment. Illegal gears such as beach seines and near-shore trawls destroy nursery habitats and remove juveniles, while *dagaa* suffers 30–40 percent post-harvest losses that diminish its economic yield (LVFO, 2018a). Forest and wetland resources are equally strained: demand for timber, charcoal, and papyrus far exceeds regeneration rates. Charcoal remains the dominant household energy source

for millions, driving widespread forest loss in Uganda and Tanzania, while unsustainable papyrus cutting reduces wetlands' ability to filter pollutants, sequester carbon, and sustain biodiversity (Waiswa et al., 2015b). Poaching for bushmeat and illegal logging further erode wildlife populations and forest cover.

As farms and settlements expand to the edges of protected areas, human–wildlife interactions have intensified. Crop-raiding by elephants and predation on livestock by lions and hyenas inflict heavy losses on local communities, often prompting retaliatory killings that weaken conservation gains (Gross et al., 2021; UNESCO, 2025). These conflicts extend beyond park boundaries and call for landscape-level planning that integrates buffer zones, compensation schemes, and community participation in wildlife management.

Climate change cuts across all these pressures. Average minimum temperatures in the basin are projected to rise by 1.3–4.5 °C by 2085, while rainfall becomes more erratic and intense (Niang et al., 2014; IWA Publishing, 2023). Warming alters lake stratification, expanding hypoxic "dead zones," while extreme floods accelerate erosion and nutrient inflows (Nyamweya et al., 2016). Droughts and storms now occur with increasing frequency, disrupting agriculture, hydrology, and fisheries. Socio-economic consequences are severe: declining crop yields, falling fish stocks, and water scarcity threaten food security and incomes, and an estimated 16–38 million people in basin countries could face climate-related displacement by 2050 (World Bank, 2021a).

3.4.5 Interconnected Threats: A Reinforcing Cycle of Degradation

These threats reinforce one another in a vicious cycle. The pressure of a growing, impoverished population drives deforestation and agricultural intensification, which leads to soil erosion and nutrient runoff that pollutes the lake and degrades its fisheries. The decline of the fisheries—a primary source of protein and income—further entrenches poverty, increasing pressure to exploit remaining terrestrial and wetland resources (UNESCO, 2025).

Deforestation and wetland loss, combined with more intense rainfall, accelerate erosion and runoff, which fuels eutrophication and invasive water hyacinth growth. Overfishing and destructive gear further collapse fish stocks, deepening poverty. In turn, vulnerable households resort to charcoal production, sand mining, or further land clearing, perpetuating the cycle of degradation.

Addressing one threat in isolation will not suffice; a coordinated, basin-wide approach that integrates land, water, biodiversity, and livelihoods is essential for breaking this cycle. A successful strategy must be integrated at a landscape level, addressing the root causes of poverty by promoting sustainable livelihoods and land-use practices that benefit both people and nature.

> "Overharvesting of fish, forests, and wetlands remains a major concern. Lake Victoria's fisheries produce about one million tonnes annually, yet unsustainable exploitation has depleted native stocks."

Table 3-3. Major Threats, Drivers, and Impacts on LVB Ecosystems

Threat Category	Specific Threat	Primary Drivers	Key Ecological / Social Impacts	Sources
Habitat Loss	Deforestation	Agricultural expansion, timber extraction, charcoal/fuelwood demand	>70% forest lost; Uganda deforestation ≈ 3.3% yr (2000–2015); soil erosion, biodiversity loss	Mango et al., 2011; Nyamweya et al., 2022
	Wetland Conversion	Farming, urban growth, weak enforcement	~33% wetland decline (1985–2014); loss of filtration and nursery functions	IPBES, 2016; IUCN, 2016
	Shoreline & Riparian Degradation	Sand/clay mining, lakeshore urbanization (+800% since 1985)	Habitat loss, turbidity, flooding	Mugo et al., 2020; Nyamweya et al., 2022
Pollution	Eutrophication	Agricultural runoff, sewage, industrial effluents, biomass burning	Algal blooms, hypoxia, fish kills	Kiwango & Wolanski, 2008; IUCN, 2019
	Chemicals & Heavy Metals	Industrial discharges, pesticides, artisanal gold mining (mercury)	Bioaccumulation in fish; health risk	Lung'ayia et al., 2001
	Plastic & Solid Waste	Poor urban waste management, fishing gear disposal	Microplastics in water & fish; ingestion hazards	Biginagwa et al., 2016).
Overexploitation	Overfishing	High demand, illegal gear (beach seines, trawls)	40% of large fish caught immature; stock decline	Nyamweya et al., 2023
	Forest & Wetland Resources	Charcoal, timber, papyrus harvesting, poaching	Unsustainable use; reduced energy security & ecological services	Nyamweya et al., 2022
Invasive Species	Water Hyacinth	Nutrient enrichment (eutrophication)	Mats block navigation, cause hypoxia	World Bank, 2021b
	Nile Perch	Species introduction (1950s)	Collapse >200 cichlids; food-web disruption	Kaufman et al., 1997; IUCN, 2019
	Lantana camara	Spread into savannas and farmlands	Forage loss >50%; crop yields ↓ 26–50%	Nyamweya et al., 2022
Climate Change	Rising Temperatures	Global GHG emissions	+1.3–4.5 °C by 2085; expanding hypoxia	Niang et al., 2014; Deirmendjian et al., 2021
	Extreme Events	More frequent storms/floods	Erosion, crop & infrastructure losses	Niang et al., 2014; IWA Publishing, 2023
	Livelihood Impacts	Interaction with poverty, resource pressures	16–38 million people at risk of climate-related displacement by 2050	World Bank, 2021a

3.5 Conservation and Sustainable Management

This section reviews the policy, institutional, and practical responses to environmental challenges in the basin. It assesses regional and national governance frameworks, conservation area networks, and on-the-ground management initiatives. The analysis identifies both successes and persistent gaps, pointing to the need for stronger regional coordination, adequate financing, and more inclusive, ecosystem-based approaches.

The Lake Victoria Basin (LVB) is managed through a complex but fragmented mix of policies, institutions, and interventions at regional, national, and community levels. These efforts have delivered important gains in coordination, conservation, and restoration, yet their overall impact is constrained by weak enforcement, insufficient resources, and a mismatch between the scale of threats and the scale of responses.

3.5.1 Policy, Legal, and Institutional Frameworks

The East African Community (EAC) has designated the LVB an *"area of common economic interest"* and established the Lake Victoria Basin Commission (LVBC) in 2003 as the lead coordinating body. The LVBC is guided by the Protocol for the Sustainable Development of the LVB, which enshrines principles of equitable use, sustainability, precaution, and "polluter pays." Its mandate spans harmonizing laws, overseeing environmental assessments, mobilizing stakeholders, and coordinating basin-wide projects. However, limited authority and funding often reduce its ability to enforce compliance across Partner States.

The Lake Victoria Fisheries Organization (LVFO) provides a complementary role, harmonizing fisheries policies and joint monitoring of stocks. While both institutions have created stronger regional dialogue, persistent differences in national enforcement and policy priorities hinder effective basin-wide management.

Partner States maintain their own environmental institutions: Kenya, Uganda and Rwanda through National Environment Management Authorities (NEMA in Kenya and Uganda, and REMA in Rwanda), Tanzania through its National Environment Management Council (NEMC), and Burundi through a environment agencies (Office Burundais pour la Protection de l'Environnement (OBPE)). These bodies operate under strong legal mandates—such as *Uganda's National Environment Act* (2019), *Tanzania's Environmental Management Act* (2004), and Rwanda's *Law No 48/2018 on the Environment*—but implementation gaps remain, particularly in land-use regulation, urban waste management, and enforcement of environmental standards.

"The Lake Victoria Fisheries Organization (LVFO) provides a complementary role, harmonizing fisheries policies and joint monitoring of stocks."

Table 3-4. Key Regional and National Institutions for Environmental Management in the LVB

Level	Institution / Body	Country / Region	Primary Mandate	Key Legal / Policy Framework
Regional	East African Community (EAC)	All Partner States	Regional integration and cooperation on economic, social, and environmental issues	Treaty for the Establishment of the EAC
	Lake Victoria Basin Commission (LVBC)	EAC Partner States	Coordinate sustainable development of the LVB; harmonize laws and policies; mobilize stakeholders	Protocol for the Sustainable Development of the LVB (2003)
	Lake Victoria Fisheries Organization (LVFO)	EAC Partner States	Harmonize fisheries management; coordinate joint monitoring and enforcement	Convention for the Establishment of the LVFO
National	National Environment Management Authority (NEMA)	Kenya	Coordinate and supervise environmental management; pollution control; EIAs	Environment Management and Coordination Act (1999)
	National Environment Management Authority (NEMA)	Uganda	Regulation, monitoring, and coordination of environmental activities; integrate environment in development	National Environment Act (2019); National Environment Policy (1994)
	National Environment Management Council (NEMC)	Tanzania	Enforcement and compliance; review of EIAs; environmental awareness	Environmental Management Act (2004); National Environmental Policy (2021)
	Rwanda Environment Management Authority (REMA)	Rwanda	Promote climate resilience, biodiversity conservation, sustainable land/water/forest use	National Environment and Climate Change Policy (2019)
	Ministry of Environment, Agriculture & Livestock (MINEAGRIE)	Burundi	Manage land, water, forests; promote sustainable agriculture and biodiversity conservation	National Environment Strategy (2016); Forestry Code

3.5.2 Conservation Area Networks and Strategies

The Lake Victoria Basin hosts a transboundary mosaic of protected areas that safeguard ecosystems ranging from montane forests and savannas to wetlands and island habitats. This network underpins biodiversity conservation—including many endemic species—and supports the basin's overall ecological integrity.

Managed by national authorities across the five riparian countries, the conservation network includes national parks, game and forest reserves, wildlife management areas, and Ramsar sites. However, growing population pressure, agricultural expansion, pollution, invasive species, and climate change continue to erode their effectiveness, underscoring the need for stronger cross-border cooperation and coordinated management.

Table 3-5. Protected Areas in the Lake Victoria Basin

Country	Protected Area	Type of Protected Area	Primary Ecoregion	Area (km2)
Burundi	Parc National de la Kibira	National Park	Albertine Rift Montane Forests	400
	Parc National de la Ruvubu	National Park	Victoria Basin Forest-Savanna Mosaic	508
	Paysage Aquatique Protégé du Nord	Ramsar Site	Victoria Basin Forest-Savanna Mosaic	162
Kenya	Masai Mara National Reserve	National Reserve	Southern Acacia-Commiphora Bushlands	1,510
	Mount Elgon National Park	National Park	East African Montane Forests	169
	Mount Elgon Forest Reserve	Forest Reserve	East African Montane Forests	737
	Mau Forest Complex	Forest Reserve (21 blocks) & Trust Land (1 block).	East African Montane Forests	~4,000 – 4,550
	Kakamega Forest National Reserve	National Reserve	East African Montane Forests	45
	Ruma National Park	National Park	Victoria Basin Forest-Savanna Mosaic	120
	Ndere Island National Park	National Park	Victoria Basin Forest-Savanna Mosaic	4.2
	Saiwa Swamp National Park	National Park	Victoria Basin Forest-Savanna Mosaic	3
Rwanda	Akagera National Park	National Park	Victoria Basin Forest-Savanna Mosaic	1,122
	Gishwati–Mukura National Park (Montane Forests)	National Park	Albertine Rift Montane Forests	34
	Nyungwe National Park (eastern watershed)	National Park	Albertine Rift Montane Forests	1,019
	Rugezi-Bulera-Ruhondo Wetland Complex	Ramsar Site	Albertine Rift Montane Forests	67
	Volcanoes National Park (Parc National des Volcans)	National Park	Rwanzori-Virunga Montane Moorlands	160

Country	Protected Area	Type of Protected Area	Primary Ecoregion	Area (km2)
Tanzania	Serengeti National Park	National Park	Serengeti Volcanic Grasslands / Southern Acacia-Commiphora Bushlands	14,763
	Burigi-Chato National Park	National Park	Victoria Basin Forest-Savanna Mosaic	4,707
	Rubondo Island National Park	National Park	Victoria Basin Forest-Savanna Mosaic	457
	Saanane Island National Park	National Park	Victoria Basin Forest-Savanna Mosaic	2.2
	Biharamulo Game Reserve	Game Reserve	Victoria Basin Forest-Savanna Mosaic	1,300
	Gurumeti Game Reserve	Game Reserve	Serengeti Volcanic Grasslands	416
	Ibanda-Kyerwa National Park	National Park	Victoria Basin Forest-Savanna Mosaic	299
	Rumanyika-Karagwe National Park	National Park	Victoria Basin Forest-Savanna Mosaic	247
	Maswa Game Reserve	Game Reserve	Southern Acacia-Commiphora Bushlands	2,200
	Ikorongo Game Reserve	Game Reserve	Serengeti Volcanic Grasslands	563
	Ikona Wildlife Management Area	Wildlife Management Area	Serengeti Volcanic Grasslands	563
	Makao Wildlife Management Area	Wildlife Management Area	Southern Acacia-Commiphora Bushlands	1,000
	Lake Victoria Ramsar Site	Ramsar Site	Victoria Basin Forest-Savanna Mosaic	13,650
Uganda	Lake Mburo National Park	National Park	Victoria Basin Forest-Savanna Mosaic	370
	Katonga Wildlife Reserve	Wildlife Reserve	Victoria Basin Forest-Savanna Mosaic	207
	Mabira Central Forest Reserve	Forest Reserve	Victoria Basin Forest-Savanna Mosaic	300
	Kalinzu Central Forest Reserve	Forest Reserve	Albertine Rift Montane Forests	137
	Ssese Islands Forest Reserves	Forest Reserves	Victoria Basin Forest-Savanna Mosaic	~173
	Lutembe Bay Wetland System	Ramsar Site	Victoria Basin Forest-Savanna Mosaic	0.98
	Mabamba Bay Wetland System	Ramsar Site	Victoria Basin Forest-Savanna Mosaic	24
	Nabajjuzi Wetland System	Ramsar Site	Victoria Basin Forest-Savanna Mosaic	17.5
	Lake Nabugabo Wetland System	Ramsar Site	Victoria Basin Forest-Savanna Mosaic	220
	Sango Bay-Musambwa Island-Kagera Wetland	Ramsar Site	Victoria Basin Forest-Savanna Mosaic	551
	Lake Mburo-Nakivale Wetland System	Ramsar Site	Victoria Basin Forest-Savanna Mosaic	135

***Note**: The areas are based on the most recent available data from national authorities, the World Database on Protected Areas (WDPA), and the Ramsar Sites Information Service. Figures can be subject to minor variations.*

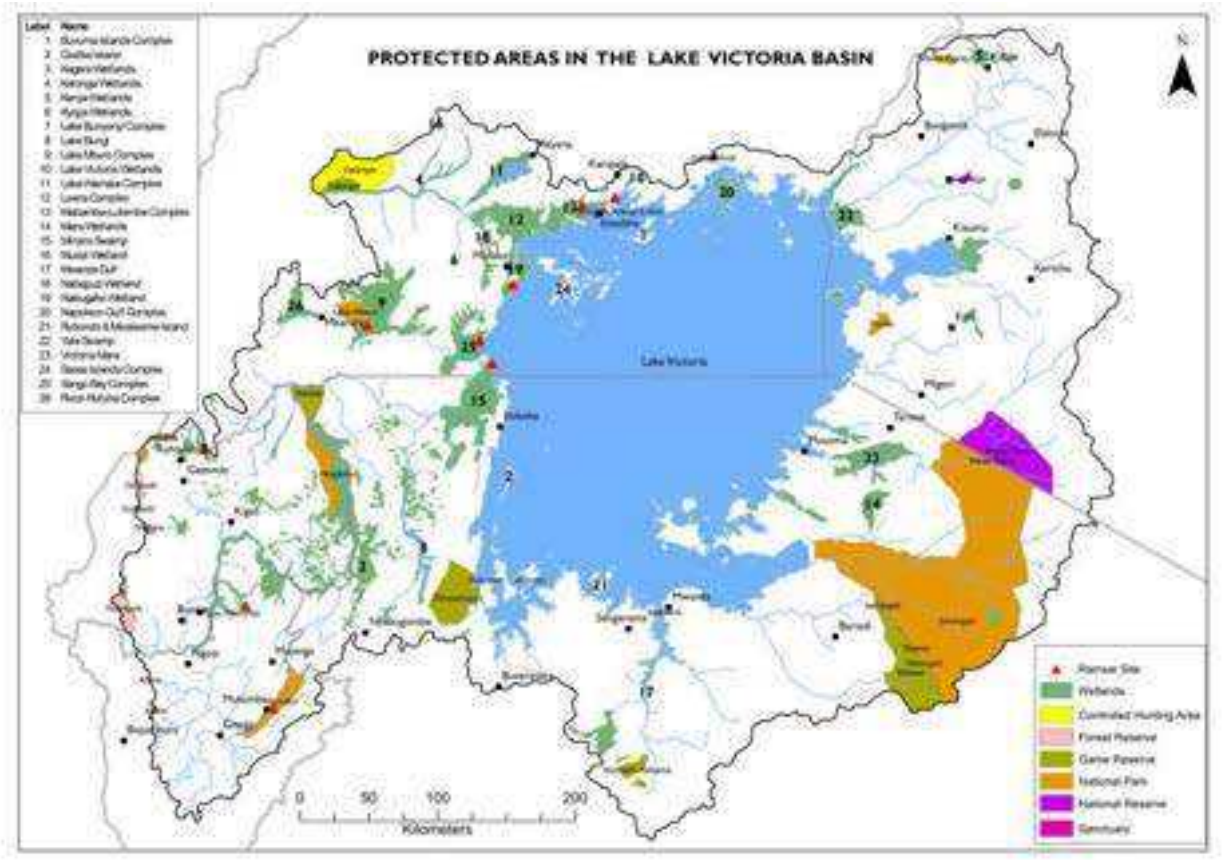


Figure 3-29. *Conservation areas in Lake Victoria Basin*

3.5.3 Management Interventions and Restoration Efforts

3.5.3.1 Integrated catchment management:

Integrated catchment management programs across the basin have promoted soil and water conservation through reforestation, buffer planting, and gully stabilization, notably reducing erosion in catchments such as Nyando in Kenya. Low-cost vegetative measures, including Vetiver grass contour planting, have effectively trapped sediments and nutrients. Recognizing that many rivers are transboundary, the Nile Basin Initiative (NBI) supports joint management plans for shared systems such as the Sio-Siteko.

3.5.3.2 Sustainable Land Use Management

Management of land use and land cover change in the Lake Victoria Basin requires coordinated, multi-level interventions that balance conservation, livelihoods, and development. Protected areas remain effective in curbing land conversion—only about 6.8% of East African protected areas and 1.6% of strictly protected sites have been converted to agriculture (Riggio et al., 2019). In the basin, key priorities include enforcing existing protections, establishing buffer zones around fragile ecosystems, and securing high-loss sub-basins such as Katonga and the forested water towers of Mau, Elgon, and Cherangani.

Forest conservation and restoration are equally critical. Programmes like LVEMP II have demonstrated the feasibility of large-scale ecosystem recovery through riverbank and

hillside reforestation. Sustaining these gains calls for preventing degazettement of forest reserves, expanding community-based forest management—which can reduce forest loss by over 90%—and scaling up REDD+ and carbon-finance initiatives aligned with continental efforts such as AFR100 and the Great Green Wall (Olaka et al., 2021; Bamwesigye et al., 2020).

Agriculture, the dominant land use, can be made more sustainable through agroforestry and other climate-smart practices that relieve pressure on forests while improving productivity. Intercropping, crop rotation, and nitrogen-fixing shrubs enhance soil fertility and carbon storage (Pretty et al., 2011; Kuyah et al., 2023). Managing bush encroachment, strengthening soil-conservation measures, and promoting Payment for Ecosystem Services schemes that reward sustainable land use are further priorities (Belayneh & Tessema, 2017; Muriuki et al., 2023).

Rapid urban growth across lakeshore cities demands planning frameworks that integrate resource management and climate resilience. Controlling sprawl, expanding access to renewable energy such as biogas and solar, and investing in green infrastructure can reduce flooding, pollution, and heat-island effects (World Bank, 2025).

Since the basin is shared among five countries, management must be coordinated regionally in line with the EAC Protocol for Sustainable Development of the Lake Victoria Basin. Regional programmes such as the LVB-IWRMP and ACC-LVB promote joint planning, cross-border adaptation, and knowledge exchange (LVBC et al., 2016–2023; UNEP & LVBC, 2016–present). Strengthening governance systems and institutional capacity remains central to these efforts.

Finally, continuous monitoring and applied research are essential for adaptive management. Satellite-based LULC tracking, field verification, and integration of indigenous knowledge will improve understanding of land-use dynamics and enable timely, evidence-based responses to emerging environmental challenges.

3.5.3.3 Community-based initiatives

Local engagement is increasingly central to conservation. Beach Management Units (BMUs) were established to give fishing communities co-management responsibilities; while compliance has been uneven, BMUs remain a foundation for community participation. NGOs have piloted wetland rehabilitation, such as the GEF-supported project in Kigungu, Uganda, which restored 35 hectares degraded by sand mining. In Kenya, community conservation areas managed with Conservation International protect fish breeding grounds. Agroforestry efforts, such as the "Forest Garden Program," now involve thousands of smallholders, improving soil health, food security, and carbon sequestration.

3.5.3.4 Large-scale programs

The **Lake Victoria Environmental Management Project (LVEMP)**, implemented in successive phases since the 1990s, remains the basin's flagship transboundary initiative for ecosystem restoration and water quality improvement. It has enhanced environmental monitoring, promoted sustainable fisheries, and supported catchment rehabilitation. However, its project-based structure has often limited continuity and institutional uptake once external funding concluded.

Complementing LVEMP, the **Lake Victoria Water and Sanitation Initiative (LVWATSAN)**—launched in 2004 by the EAC with support from UN-Habitat and the African Development Bank—has channelled significant investment into urban water and sanitation infrastructure. Implemented in two phases across all Partner States, it has improved water and sanitation access for over **780,000 people**, strengthened urban management capacity, and contributed to reducing nutrient and wastewater loads into the lake. Yet with only a small proportion of the basin's secondary towns reached, the program highlights both progress achieved and the

3.5.4 Managing the Transboundary Ecosystems of the Lake Victoria Basin

Transboundary ecosystems—lakes, rivers, wetlands, forests, and wildlife corridors that straddle two or more countries—function as single ecological units despite political boundaries (EAC, 2004). In the Lake Victoria Basin, water, sediments, wildlife, and pollutants flow freely across borders, and climate risks are shared. These realities make national-scale interventions insufficient and call for coordinated regional stewardship.

The Lake Victoria Basin is an ecological mosaic of open waters, savannahs, montane forests, rivers, and wetlands functionally linked through hydrology, migration routes, and climate. Critical transboundary ecosystems include:

- **Lake Victoria** (Kenya–Tanzania–Uganda; basin includes Burundi and Rwanda): the world's largest tropical lake, shallow and nutrient-sensitive; once hosted over 500 endemic cichlids, now dominated by Nile perch and tilapia amid eutrophication and invasive species (Machiwa, 2003; IUCN, 2018).
- **Serengeti–Mara** (Kenya–Tanzania): an iconic savanna supporting the wildebeest migration and large carnivore populations, threatened by water abstraction and land conversion (UNESCO WHC, 2017).
- **Nyungwe–Kibira Forests** (Rwanda–Burundi): the region's largest montane forest block on the Congo–Nile divide, rich in Albertine Rift endemics and primates but under pressure from encroachment (Uwiragiye et al., 2023).
- **Volcanoes–Virunga–Mgahinga** Massif (Rwanda–Uganda–DRC): a contiguous volcanic ecosystem and stronghold of the endangered mountain gorilla.
- **Mount Elgon** (Kenya–Uganda): a transboundary "water tower" feeding Lakes Victoria, Kyoga, and Turkana; increasingly affected by encroachment and landslides (UNESCO, 2025).
- **Kagera River** (Burundi–Rwanda–Tanzania–Uganda): the lake's largest inflow, with extensive wetlands degraded by erosion and drainage (Van der Knaap et al., 2002).
- **Sio–Siteko System** (Kenya–Uganda): shared wetland and floodplain critical for fisheries and flood control, degraded by cultivation and agrochemical runoff (NBI, 2020).

Managing such systems is complicated by sovereignty concerns, uneven legal standards, weak border enforcement, fragmented monitoring, and unequal cost–benefit sharing between upstream and downstream states. These gaps often enable illegal logging, poaching, and resource encroachment.

To address them, riparian countries have developed several bilateral and ecosystem-specific frameworks: the Kenya–Tanzania MoU on Mara River management and the 2023 "12 Resolutions for the Mara"; the 2008 Rwanda–Burundi MoU for joint patrols in Nyungwe–Kibira; the Kenya–Uganda arrangement for Mount Elgon's biosphere reserve; and NBI/NELSAP initiatives for the Kagera and Sio–Siteko wetlands (WWF, 2023; NBI, 2020).

Regional governance rests on the EAC Treaty and the *Protocol for the Sustainable Development of the LVB (2004)*, which commit Partner States to joint resource management, harmonized laws, environmental assessments, and public participation (EAC, 2004). The LVBC serves as the coordinating body, while international partners—such as the World Bank, GEF, GIZ, EU, and UNEP—provide finance and technical support through regional programs including LVEMP and ACC-LVB. Global designations like the Serengeti World Heritage Site and the Mount Elgon Transboundary Biosphere Reserve further enhance conservation standards and international visibility (UNEP-WCMC, 2020; UNESCO, 2025).

3.5.5 Effectiveness of Management Interventions: What's Working and What Isn't

After more than two decades of regional cooperation and substantial investment, ecosystem management in the Lake Victoria Basin presents a mixed picture. Donor-supported and bilateral initiatives have delivered tangible local gains, yet these have not produced basin-wide ecological recovery. Weak enforcement, limited financing, and fragmented institutional coordination continue to constrain long-term effectiveness.

Notable successes include the biological control of water hyacinth, which reduced infestations to manageable levels and reopened key waterways, as well as harmonized fisheries regulations and the establishment of Beach Management Units that enhanced community participation in resource governance. Bilateral law-enforcement efforts—such as joint patrols in the Serengeti–Mara and Nyungwe–Kibira landscapes—have curbed poaching and strengthened intelligence sharing (Hilborn et al., 2006; EEAS, 2019). These achievements show that well-funded, targeted interventions can yield measurable benefits.

However, progress remains uneven. Many programs rely on short donor cycles, losing momentum when funding ends. National agencies remain under-resourced, and border zones are difficult to police. Regional protocols are slow to be domesticated into enforceable national laws, creating inconsistent standards across Partner States (EAC, 2004). Weak data coordination and limited basin-wide monitoring further hinder adaptive management. Most importantly, interventions have not addressed the underlying socio-economic pressures—poverty, population growth, and land-use change—that perpetuate degradation.

The basin thus faces an implementation paradox: policies, protocols, and institutions exist, but they are not matched by the sustained political commitment, financial resources, or enforcement capacity needed for transformative change. Management remains reactive and project-based rather than integrated, long-term, and systemic.

3.6 Trends, Outlook, and Recommendations

The Lake Victoria Basin (LVB) is at a defining moment. Long-term pressures from rapid population growth, land conversion, urbanization, and climate change have eroded ecosystems, reduced biodiversity, and strained the natural capital that underpins regional economies. This section reviews recent trends, identifies monitoring challenges, explores alternative futures, and sets out strategic recommendations to guide countries toward sustainable management.

3.6.1 Observed Trends

Recent trends show accelerating land-use change, declining water quality, and deep ecological shifts. Urban areas expanded nearly ninefold between 1985 and 2014, while forests and wetlands have declined sharply (Mugo et al., 2020; FAO, 2019). Eutrophication and pollution have worsened, and the fishery is now dominated by Nile perch, Nile tilapia, and dagaa, with most endemic cichlids lost (Nyamweya et al., 2022). Flagship species such as the Shoebill and Sitatunga continue to decline due to habitat loss and hunting (BirdLife International, 2020; IUCN, 2016).

Two broad futures emerge. Under a **business-as-usual** pathway, degradation of land, forests, and wetlands will intensify, while unchecked urban growth and climate warming of 1.3–4.5°C will exacerbate floods, droughts, and displacement—potentially affecting up to 38 million people by 2050 (Olaka et al., 2019; World Bank, 2021a). By contrast, a sustainable management pathway would scale up integrated water and land management, wetland restoration, reforestation, and urban sanitation. Strengthened fisheries governance, aquaculture, and eco-tourism could sustain biodiversity and local economies (Aura et al., 2022).

The choice is stark: persist with fragmented, short-term efforts and risk ecological collapse, or commit to basin-wide cooperation, long-term investment, and community-driven restoration to secure both nature and livelihoods.

3.6.2 Strategic Recommendations

Sustainable management of the Lake Victoria Basin requires coordinated policy reform, effective implementation, knowledge-driven decision-making, and community participation. The recommendations below focus on scaling up successful initiatives, addressing structural drivers of degradation, and building institutional and financial resilience.

Policy and Governance

Strong, enforceable governance remains the cornerstone of basin management. Regional frameworks exist but are unevenly applied, and enforcement is weak. Partner States should:

- Harmonize regulations and penalties on water, land, fisheries, and pollution, and enforce basin-wide standards for effluents, agrochemicals, and water quality (EAC, 2003; LVBC, 2023).
- Integrate natural capital accounting into economic and investment planning across key sectors.
- Strengthen regional institutions—especially the LVBC and LVFO—through expanded mandates, predictable financing, and stronger compliance monitoring (EAC, 2004; GIZ, 2022).
- Institutionalize cross-sector coordination platforms linking water, environment, agriculture, tourism, and finance.
- Fast-track regional legal instruments such as the EAC Transboundary Ecosystems Management Bill and Wildlife Conservation Policy.
- Scale up joint ecosystem management plans for priority sites including Serengeti–Mara, Nyungwe–Kibira, and Sango Bay–Minziro.

Management

Interventions must address root causes while improving livelihoods. Key priorities are:

- Expanding long-term landscape restoration—reforestation, wetland rehabilitation, and agroforestry (Waiswa et al., 2015a).
- Investing in pollution control through improved urban sanitation and wastewater management (Awange, 2021).
- Enforcing against illegal fishing, logging, charcoal production, and sand mining (Nyamweya et al., 2022).
- Implementing an Integrated Basin Ecosystem Management Plan with basin-wide targets for nutrient reduction, habitat connectivity, and climate adaptation.

Research and Monitoring

Adaptive management depends on reliable, shared data.

- Re-establish coordinated monitoring networks for water quality, land use, and biodiversity, building on the LVEMP framework (Mango et al., 2011).
- Fill critical research gaps on hydrology, threatened species, and socio-economic drivers.

- Create a basin-wide data-sharing system and integrated environmental information platform for real-time reporting (LVBC, 2023).

Communities and Stakeholders

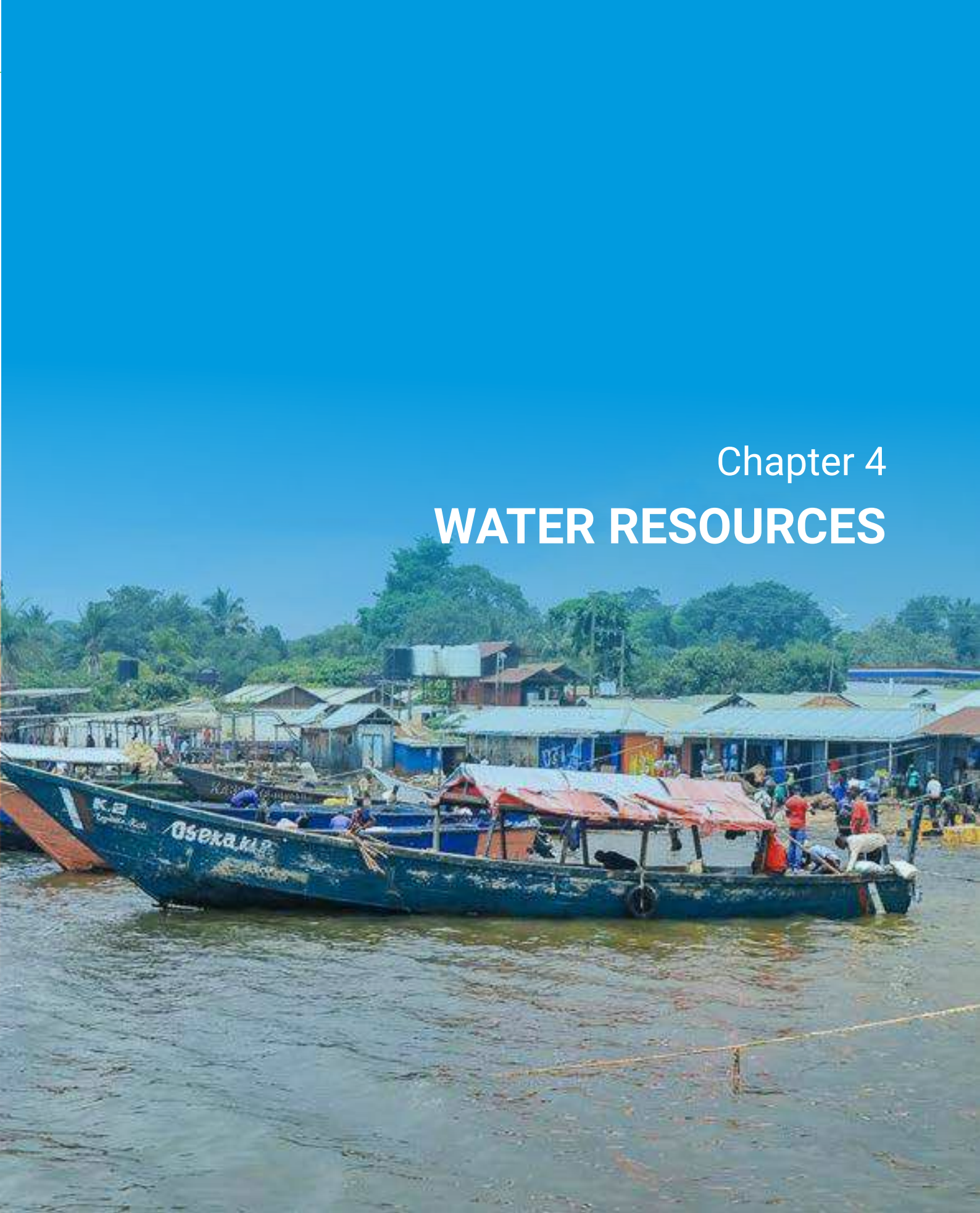
Lasting change depends on empowered local participation and equitable benefits.

- Strengthen BMUs and Water User Associations through funding, training, and legal recognition.
- Promote alternative livelihoods—especially aquaculture, eco-tourism, and climate-smart agriculture.
- Integrate indigenous and local knowledge into resource planning.
- Devolve co-management rights and ensure transparent benefit-sharing.
- Establish sustainable financing through Water Funds, Payments for Ecosystem Services, and transboundary tourism revenue-sharing schemes.

Together, these actions form an integrated strategy linking governance reform, ecosystem restoration, and inclusive development to secure the ecological and socio-economic resilience of of Sustainable Development.

Chapter 4

WATER RESOURCES



SUMMARY CHAPTER 4

Chapter 4 provides an integrated assessment of the Lake Victoria Basin's physical water resources foundation—its climate system, surface water hydrology, groundwater reserves, and the monitoring and data frameworks that underpin water governance. It synthesises long-term climatic trends, river and lake dynamics, and aquifer behaviour to show how climate variability, land-use change, and rising demand are reshaping the basin's hydrological regime. The chapter then examines the strengths and gaps of basin-wide water resources monitoring as a cornerstone of transboundary management. It concludes by distilling the basin's key water management challenges and framing strategic, forward-looking recommendations for addressing them.



Climate of the LVB

Rainfall is the dominant driver of basin hydrology, with a bimodal regime and extreme spatial variability—exceeding 2,000 mm/year in the western basin but falling below 900 mm/year in the semi-arid southeast.



Surface Water Resources

Lake Victoria's surface water system is centripetal, with 23 heterogeneous sub-basins draining its 193,000 km2 terrestrial catchment.



Water Resources Monitoring

The LVB is emerging from a historical "data vacuum" into a modernized, but uneven, monitoring era, with significant upgrades in Kenya, Rwanda and Uganda contrasted by serious blind spots in Burundi and parts of Tanzania.



Groundwater Resources

Large groundwater storage masks tight recharge constraints, making sustainable yield—not total storage—the true development limit, especially in major systems such as the Kagera Aquifer.

Climate of the LVB

1. Lake Victoria actively shapes the basin's climate, functioning as a quasi-ocean that drives strong lake–land breeze circulations, nocturnal convection, and pronounced east–west rainfall contrasts.
2. Rainfall is the dominant driver of basin hydrology, with a bimodal regime and extreme spatial variability—exceeding 2,000 mm/year in the western basin but falling below 900 mm/year in the semi-arid southeast.
3. The lake's water balance is exceptionally sensitive to climate variability, as precipitation and evaporation are nearly equal; modest anomalies can trigger multi-metre lake level changes.
4. Extreme events are intensifying under ocean–atmosphere controls, with positive Indian Ocean Dipole phases driving record floods (1961/62, 2019/20), while droughts continue to constrain water and energy security.

Surface Water Resources

5. Lake Victoria's surface water system is centripetal, with 23 heterogeneous sub-basins draining its 193,000 km2 terrestrial catchment.
6. Stream runoff regimes fall into three distinct hydrological behaviour classes—buffered perennial, bimodal flashy, and semi-arid episodic—creating strong contrasts in flow reliability, drought exposure, and flood risk.
7. A small number of rivers dominate inflow, with the Kagera and major Kenyan tributaries (Nzoia, Yala, Nyando, Gucha, Sondu, etc.) providing the bulk of riverine discharge and sediment loading to the lake.

8. Modernizing the Agreed Curve is now an urgent priority, requiring its integration into a forecast-informed, climate-adaptive operating framework with differentiated operational rules for droughts, floods, and extreme events, supported by real-time monitoring, basin-wide abstraction accounting, coordinated hydropower cascade optimization, and benefit-sharing mechanisms.

Groundwater Resources

9. Groundwater is a strategic drought buffer and the backbone of rural water supply, sustaining 60–90% of rural populations and maintaining dry-season river baseflows and wetlands.
10. The basin's groundwater resource is highly heterogeneous, dominated by low-yield, fracture-controlled basement aquifers, with high-productivity confined to localized volcanic and alluvial systems.
11. Large groundwater storage masks tight recharge constraints, making sustainable yield—not total storage—the true development limit, especially in major systems such as the Kagera Aquifer.
12. Transboundary aquifers are critically important but weakly governed, with Mount Elgon, Sio–Malaba–Malakisi, and Kagera systems lacking formal cooperative management despite strong cross-border hydraulic connectivity.
13. Groundwater faces a growing "silent risk" from rising abstraction and weak monitoring, as projected demand may exceed safe yields in key aquifers by 2050.

Water Resources Monitoring

14. The LVB is emerging from a historical "data vacuum" into a modernized, but uneven, monitoring era, with significant upgrades in Kenya, Rwanda and Uganda contrasted by serious blind spots in Burundi and parts of Tanzania.
15. Monitoring networks are in technological transition, combining dense but fragile legacies of manual gauges with expanding telemetry, ADCP use, and Automatic Weather Stations, yet functionality often lags behind installed capacity.
16. Critical spatial and parameter gaps persist, notably in headwater catchments, open-lake meteorology, sediment loads, and groundwater quality—leaving major uncertainties in the water balance, infrastructure lifespan, and public-health risks.
17. Basin-wide information platforms, especially LVB-WIS, are transformative but not yet fully operational, and their impact will depend on sustained national data feeds, interoperability, and staff capacity.
18. Robust legal frameworks for transboundary data sharing exist but are undermined by sovereignty concerns, bureaucratic friction, and technical incompatibilities, making effective, real-time exchange of water information as much a political challenge as a technical one.

Key Challenges and Recommendations

19. Integrate seasonal forecasts into dam operations, apply adaptive lake level rules, strengthen flood–drought early warning, and climate-proof monitoring infrastructure.
20. Deploy telemetered groundwater networks, undertake sustainable yield assessments, regulate irrigation abstraction, and formalize cooperative aquifer management.
21. Densify headwater networks (especially Burundi), expand open-lake meteorology, sediment and real-time water quality monitoring, and strengthen hydro-informatics capacity.
22. Fully operationalize LVB-WIS, harmonize formats and QC standards, automate near–real-time sharing, and update rating curves routinely.
23. Stabilize national budget allocations for water resources monitoring network operation, establish dedicated maintenance funds, introduce beneficiary-based cost recovery, and create regional calibration centers.



Figure 4-1. *Nzoia Rive in Western Kenya (Source: Abiri Kenya)*

Key State Indicators – Water Resources Management and Development (2025)

Strategic & Thematic Areas	Indicator / Metric	Value / Range (2025)
W1 Water resources availability		
W1.1 Surface water (streamflow)	Mean river inflow to Lake Victoria	729.3 m³/s
	Annual river inflow volume	~23 BCM per year
W1.2 Groundwater potential	Renewable recharge – Lake Victoria North Catchment Area (LVNCA)	1,326 MCM per year
	Renewable recharge – Lake Victoria South Catchment Area (LVSCA)	2,294 MCM per year
	Renewable recharge – Rwizi catchment	875 MCM per year
	Renewable recharge – Katonga catchment	402 MCM per year
	Renewable recharge – Akanyaru catchment	531 MCM per year
	Renewable recharge – Nyabarongo catchment	545 MCM per year
	Renewable recharge – Tanzania LVB catchments	1,327 MCM per year
	Total renewable groundwater recharge	~7,300 MCM per year
W1.3 Lake levels	Status of lake level variability and trends	Lake Victoria levels fluctuate significantly (about 4 meters range over past 75 years); notable peak in the early 1960s (~1,136m); also notable sharp decline in the early 2000s, reaching lowest point around 2006 (~1,133.3m); this was followed by strong recovery since 2006, with 2020-2025 showing highest levels in the entire record (~1,136-1,136.5m)
W3 Monitoring		
W3.1 Hydromet monitoring	Streamflow monitoring stations	179 stations
	Lake level monitoring stations	14 stations
	Hydrometeorological and climatic stations	290 stations
	Functional monitoring stations	55 %
W3.2 Groundwater monitoring	Groundwater monitoring stations	117 stations
	Functional groundwater stations	94 %
W3.3 Water quality monitoring	Lake water quality monitoring stations	57 stations
	River water quality monitoring stations	No information

4.1 Climate

The climate of the Lake Victoria Basin (LVB) is shaped by its equatorial setting, the thermal and moisture influence of Lake Victoria, and the complex orography of the surrounding highlands. These features generate pronounced spatial variability in rainfall, temperature, and evapotranspiration, with implications for hydrology, water security, and ecosystem resilience. An overview of the current climate is provided here; detailed analysis of long-term trends is presented in **Chapter 7**.

4.1.1 Physical Drivers and Spatiotemporal Variability of the LVB Climate

Basin Location and Climatic Setting

The Lake Victoria Basin (LVB), covering 259,800 km², occupies a unique position within the East African highlands where complex topography and a vast inland water body combine to create one of Africa's most distinctive hydro-climatic regimes. Rather than simply receiving regional weather systems, the basin actively modifies them; Lake Victoria generates strong mesoscale circulations that contribute substantially to local rainfall and convective intensity (Thiery et al., 2016; Nicholson, 2017).

The elevation within the Lake Victoria Basin is a primary determinant of rainfall distribution, temperature gradients, and river channel gradients. The basin exhibits a dramatic elevation range, extending from approximately 1,134 meters above sea level (masl) at the lake surface to over 4,500 masl in the mountainous distinct headwaters of the Kagera and Nzoia systems.

- **The Highlands**: The eastern rim of the basin is bounded by the Mau Escarpment, Nandi Hills, and Mount Elgon (4,321 masl) in Kenya. To the west, the basin is framed by the precipitous highlands of Rwanda and Burundi, including the Virunga volcanoes, where elevations frequently exceed 3,000 masl. These high-altitude zones act as the "water towers" of the basin, intercepting moisture and generating the majority of the runoff.
- **The Plateaus and Plains**: Transitioning from the highlands, the terrain flattens into extensive plateaus and rolling hills, particularly evident in the Tanzanian sub-basins like the Simiyu and Mbalageti, and the Kano plains that are part of the Nyando sub-basin. These areas, ranging between 1,200 and 1,500 masl, are characterized by lower gradients, reduced stream power, and increased sediment deposition.

The Lacustrine Lowlands: Surrounding the lake shore is a littoral zone of wetlands and low-lying floodplains. This zone, typically below 1,200 masl, acts as a buffer, attenuating floods and filtering sediments before they enter the lake.

Equatorial Highland Setting

Although situated within the equatorial belt, the LVB exhibits a Modified Equatorial Climate shaped by altitude and terrain. High solar loading supports vigorous convection, but plateau elevations of 1,000–1,500 m temper temperatures, while rift-flank mountains generate substantial orographic uplift and localised high-rainfall zones (Nicholson, 2017; Kizza et al., 2009). These highlands separate the moist lake-influenced interior from the drier peripheral plains.

The "Quasi-Oceanic" Influence of Lake Victoria

Lake Victoria—68,800 km² and the world's largest tropical lake—functions as a quasi-ocean whose thermal inertia dominates basin meteorology. Its relatively stable surface temperatures (24–26°C) drive persistent land–lake breeze

circulations and a strong nocturnal convergence zone over the lake, resulting in intense nighttime thunderstorms and a low diurnal temperature range across adjacent regions (Thiery et al., 2016; Sun et al., 2015). This mesoscale system creates a distinctive "lake climate" that gradually gives way to semi-arid conditions in the outer hinterlands.

Climate Controls and Drivers

LVB climate is shaped by interacting controls across spatial and temporal scales.

- **Solar forcing and ITCZ migration** govern the basin's bimodal rainfall pattern, with peaks following the equatorial passage of the sun (Nicholson, 2017).
- **Topography** modulates moisture distribution: the Mau and Nandi escarpments enhance rainfall via orographic lifting, while their leeward zones experience rain-shadow effects (Kizza et al., 2009).
- **Ocean–atmosphere teleconnections**, notably ENSO and the Indian Ocean Dipole (IOD), drive interannual variability. Recent evidence shows positive IOD events as the dominant trigger of extreme wet seasons such as 1961, 1997, and 2019 (Thiery et al., 2021).
- **Mesoscale lake–land circulations** structure rainfall into marked east–west contrasts, with nocturnal maxima over and west of the lake (Thiery et al., 2016).

Climate Classification

Under the Köppen–Geiger system, the basin forms a climatic mosaic: **Af** conditions over the lake and humid western littoral, **Am** and **Aw/As** in the southern and eastern plains with distinct dry seasons, and **Cfb/Cwb** temperate climates in the highlands (Beck et al., 2018). This spatial diversity reflects the interplay of lake influence, elevation, and large-scale circulation patterns. The **Table 4-1** shows the key climatic zones with the lake basin.

Table 4-1. Climatic Zones and Rainfall Characteristics of the Lake Victoria Basin

Climatic Zone	Köppen Classification	Representative Areas	Rainfall Characteristics	Hydrological Relevance
Lake Surface & Shoreline	Af (Tropical Rainforest)	Ssese Islands, Kalangala, Entebbe	High (1,600 – 2,400 mm); Nocturnal peaks; Low seasonality.	Dominant input to Lake Water Balance (~82%); high precipitation efficiency.
Western & Northern Highlands	Am (Tropical Monsoon) / Cfb (Temperate)	Kagera headwaters (Rwanda/Burundi), Mt. Elgon (Uganda/Kenya)	High (1,200 – 1,800 mm); Orographic enhancement; Reliable bimodal pattern.	Primary sources of riverine inflow (Kagera, Nzoia); "Water Towers" of the basin.
Eastern Highlands	Cfb / Cwb (Montane)	Mau Forest Complex, Cherangany Hills	Moderate to High (1,200 – 1,600 mm); Cool temperatures reducing PET.	Critical headwaters for Mara, Sondu, Nyando, Yala rivers; high erosion potential.
Southern & Eastern Plains	Aw (Tropical Savanna) / BSh (Hot Semi-Arid)	Simiyu/Mbalageti basins (Tanzania), Kano Plains (Kenya)	Low to Moderate (700 – 1,000 mm); Highly seasonal; High PET.	Source of ephemeral rivers; high water stress; vulnerable to drought.

Source Data: *Synthesized from NBI (2016); Peel et al. (2007); Rwetabula et al. (2007);*

4.1.2 Temperature

Temperature patterns in the Lake Victoria Basin (LVB) display the characteristic stability of equatorial regions, yet are strongly modulated by elevation and the moderating influence of Lake Victoria. Mean annual temperatures vary only modestly across seasons, while diurnal and spatial differences are more pronounced.

Spatial Variation of Mean Annual Temperature

A clear altitudinal gradient defines the basin's thermal structure. The warmest conditions occur in the low-elevation lacustrine plains of the Nyanza Gulf and the semi-arid margins of northern Tanzania, where mean annual maximum temperatures often reach 28–30°C, with dry-season peaks above 32°C (Figure 4-2; Table 4-2). In contrast, highland areas such as the Mau Escarpment, Mount Elgon, and the Rwandan–Burundian uplands routinely record mean annual temperatures below 18°C, with nighttime minima in some locations falling below 10°C (Beck et al., 2018).

Lake Victoria itself maintains a remarkably stable surface temperature of ~24°C year-round, acting as a local heat reservoir that raises nighttime temperatures along the shoreline (Sun et al., 2015).

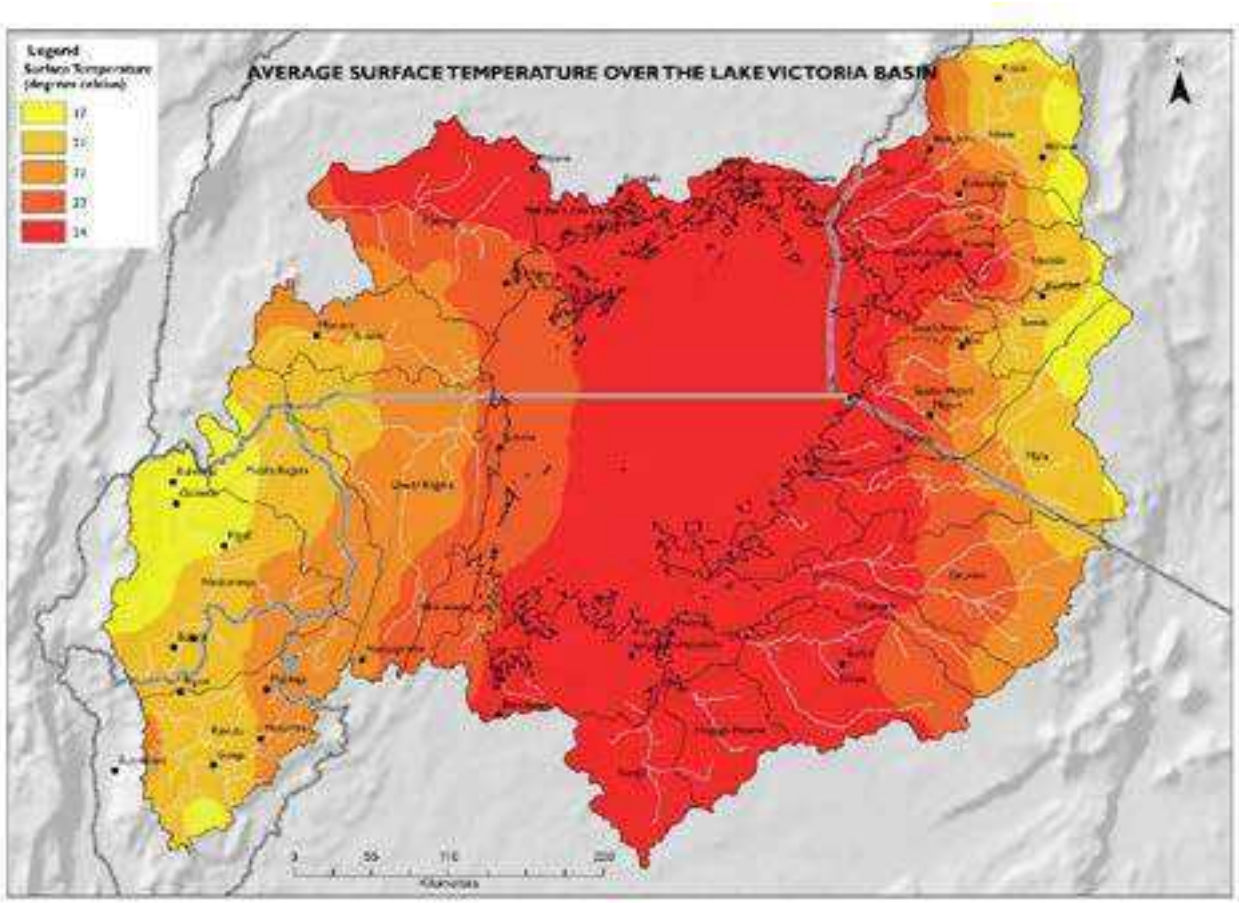


Figure 4-2. *Variation of surface temperature over the Lake Victoria Basin.*

Table 4-2. **Representative Temperature Characteristics of Selected Basin Zones**

Location/ Zone	Köppen Classification	Elevation (m)	Mean Annual Max (°C)	Mean Annual Min (°C)	Thermal Characteristic
Kisumu	Lake Shore (Equatorial)	1,135	29–30	18–19	Warm nights; low DTR due to lake effect
Entebbe	Lake Peninsula (Equatorial)	1,150	25–27	17–18	Very low DTR; strong lake moderation
Mwanza	Southern Shore (Savanna)	1,140	27–28	16–17	Moderate seasonality; cooler dry-season nights
Kabale	Highlands (Temperate)	2,000	23–24	9–11	High DTR; significantly cooler overall
Lake Surface	Lacustrine	1,134	~24	~23.5	Extremely stable; nighttime heat source

Source Data: *Sources: Evans et al., 2020; Sun et al., 2015*

Seasonal Temperature Variation

Although seasonality is muted, temperature follows predictable annual rhythms linked to solar position and cloud cover. The warmest period occurs in February–March, just before the long rains, when maximum temperatures in lowland stations commonly reach 29–31°C. A secondary warm peak appears in October ahead of the short rains.

The coolest months are June–July, when the Southeast Monsoon brings drier, cooler air and extensive morning cloudiness suppresses surface heating. During this period, maximum temperatures at shoreline stations such as Entebbe and Bukoba can drop to 24–25°C (Nicholson, 2017).

Diurnal Temperature Variation

Diurnal range is the dominant expression of thermal variability in the LVB. Proximity to the lake markedly reduces the diurnal temperature range (DTR), with stations on peninsulas and islands showing DTR values of 7–9°C due to strong nocturnal warming by the lake. Inland and semi-arid zones experience substantially larger swings of 12–15°C, driven by clearer skies, lower humidity, and rapid nighttime radiative cooling (Sun et al., 2015).

Key Controls on Temperature

Temperature regulation in the basin is shaped by three principal controls:

- **Lake thermodynamics:** The lake's high heat capacity produces stable surface temperatures (~24°C), moderating extremes and anchoring local nighttime warming. Sensitivity experiments show that even modest anomalies in lake surface temperature can influence convection and boundary-layer processes basin-wide (Sun et al., 2015).
- **Elevation:** A relief of more than **2,000 m** creates strong lapse-rate effects that underpin the basin's diverse agro-ecological zones, from cool highland crops to warm lowland systems (Beck et al., 2018).
- **Cloud cover:** Persistent cloudiness—especially in the lake's western sector—reduces daytime insolation while trapping longwave radiation at night, narrowing the diurnal temperature range (Thiery et al., 2016).

4.1.3 Rainfall

Rainfall is the dominant climatic and hydrological driver in the Lake Victoria Basin (LVB), supplying roughly **80% of lake inflow** and sustaining predominantly rain-fed livelihoods across the region.

Mechanisms of Rainfall Formation

Precipitation in the LVB is overwhelmingly convective, shaped by interactions between synoptic easterlies and strong lake–land breezes. Mesoscale convective systems develop as the diurnal lake circulation alternates between daytime divergence over the lake and nocturnal convergence, producing the well-documented early-morning thunderstorms over the lake surface (Thiery et al., 2016; Camberlin et al., 2018). In the western basin, the Congolese Air Boundary provides an additional lifting mechanism, functioning as a quasi-frontal zone separating moist westerlies from drier easterlies (Nicholson, 2017).

Spatio-temporal patterns

The lake's circulation generates a pronounced east–west rainfall dipole, with the western and northwestern shores—such as Entebbe and Bukoba—receiving 2,000–2,500 mm/year due to strong nocturnal convergence as accelerated easterly winds traverse the lake and meet opposing land breezes, while the eastern and southeastern shores, including Karungu, Musoma, and the Serengeti margin, receive only 700–900 mm/year as daytime divergence and subsidence suppress rainfall on the lee side of the easterlies (Kizza et al., 2009; Thiery et al., 2016; Nicholson, 2017) (Figure 4-3).

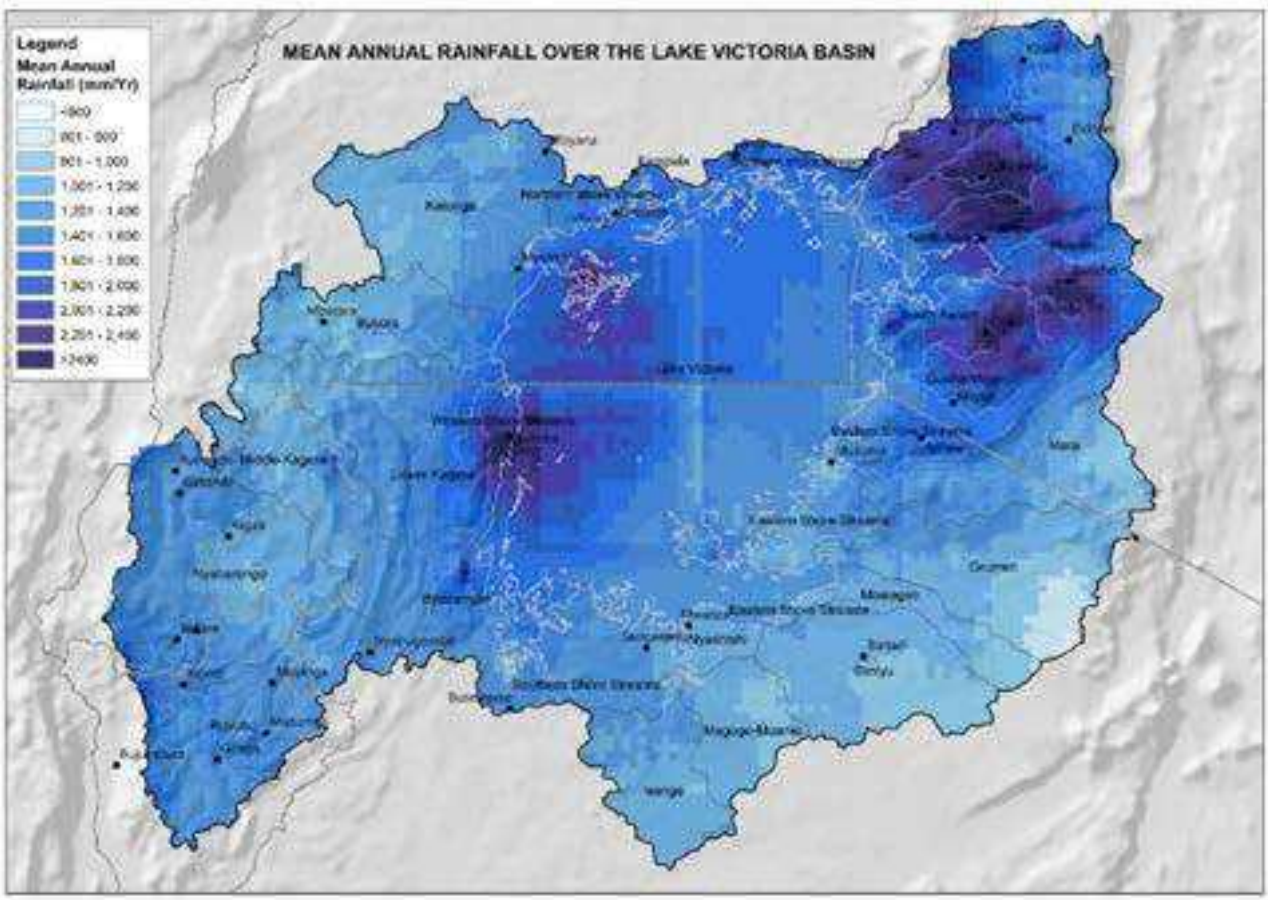
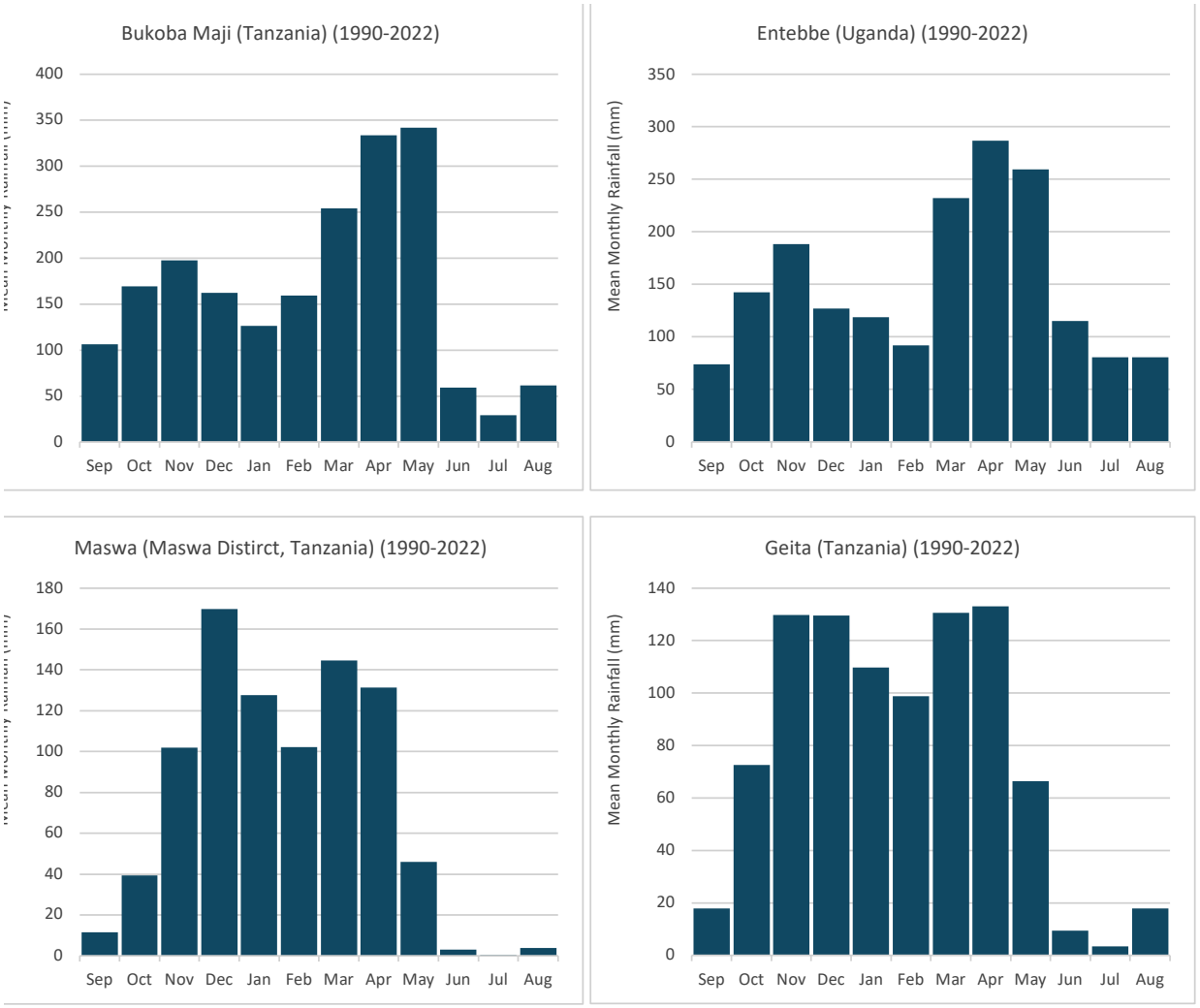


Figure 4-3. *Variation of mean annual rainfall over the Lake Victoria Basin.*

The basin exhibits a bimodal rainfall regime governed by ITCZ migration: the Long Rains (MAM) form the principal season and typically peak in April, often generating widespread flooding in wet years; the Short Rains (SON) are more variable yet increasingly dominant, showing strong sensitivity to Indian Ocean conditions; and the dry seasons (January–February and June–September) remain relatively wet along the shoreline, where persistent lake-induced convection maintains monthly totals above 100 mm (Figure 4-4). Owing to this lake modulation, shoreline areas experience no fully dry month, distinguishing the LVB from surrounding regions.



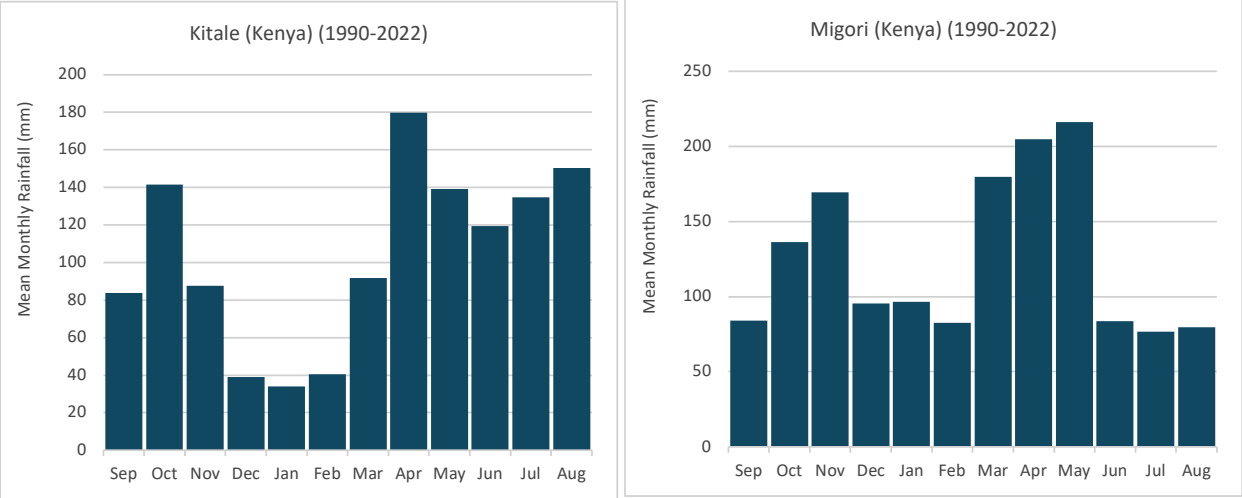


Figure 4-4. *Variation Mean monthly rainfall in selected stations in the Lake Victoria Basin (of mean annual rainfall over the Lake Victoria Basin. (Source: National Hydrological Service of the LVB Partner States).*

Rainfall Intensity and Reliability

Rainfall events are frequently intense, with storm rates exceeding 25–50 mm/hr and extreme daily totals surpassing 100 mm during large convective outbreaks (Thiery et al., 2016). Reliability mirrors spatial gradients: the wet western sector exhibits low variability, whereas the semi-arid southeast shows coefficients of variation above 30%, contributing to recurrent agricultural failures (Kizza et al., 2009). Seasonal onset and cessation generally follow classical patterns (MAM onset in mid-March; SON onset mid-October), though recent years show extended SON seasons, occasionally merging into early-year rains (Liebmann et al., 2012).

Interannual Variability and Large-Scale Drivers

Interannual variability is dominated by coupled ocean–atmosphere modes. Recent evidence highlights the Indian Ocean Dipole (IOD) as the principal driver of extreme wet years, including the 2019–2020 event that produced record-breaking lake levels through unusually prolonged and intense SON rains (Thiery et al., 2021). While the historical "*East African Paradox*" reflected a mismatch between predicted wetting and observed drying, the increasing frequency of extreme rains since 2010 suggests a renewed transition toward the long-anticipated wetting trend (Nicholson, 2017).

4.1.4 Evaporation and Potential Evapotranspiration (PET)

Mean Annual Evaporation and PET

Evaporation from Lake Victoria is primarily energy-limited, controlled by solar radiation and wind speed rather than water availability. Despite historical uncertainties, recent syntheses converge on 1,500–1,600 mm/year as the evaporation over the lake surface **(Figure 4-4)**, a value strikingly close to the lake's mean annual rainfall of ~1,525 mm, underscoring the lake's finely balanced hydrological budget (Vanderkelen et al., 2018).

Across the land catchment, Potential Evapotranspiration (PET) shows strong spatial contrast. The semi-arid southeastern basin exhibits the highest atmospheric moisture demand, with PET exceeding 1,800–2,000 mm/year, reflecting high temperatures and low humidity (Yin & Nicholson, 1998). In contrast, the humid western highlands experience substantially lower PET—roughly 1,200–1,400 mm/year—due to cooler conditions and persistent cloud cover that suppress incoming solar radiation.

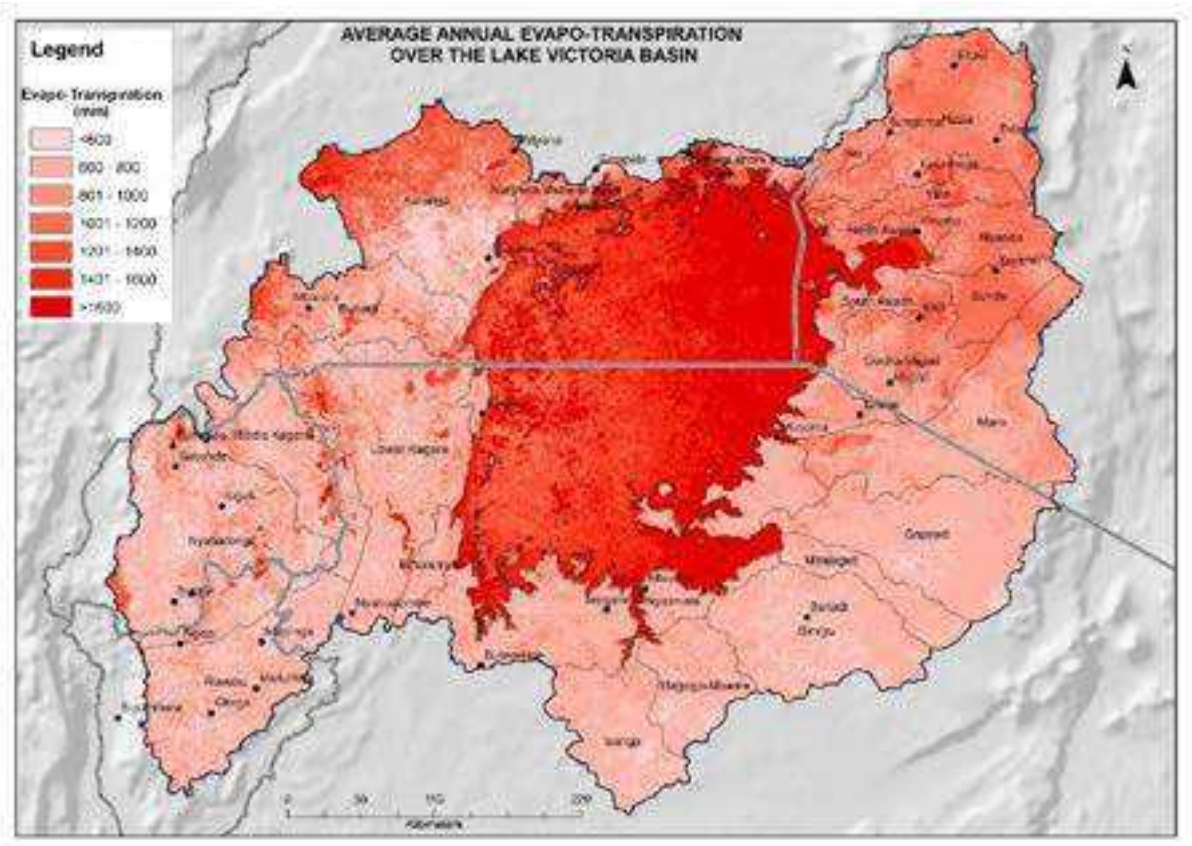


Figure 4-5. *Variation of mean annual evapotranspiration over the Lake Victoria Basin.*

Seasonal Patterns

Although less variable than rainfall, evaporation and PET display clear seasonal rhythms. Peak evaporation occurs in January–February and July–October, when reduced cloud cover increases solar heating and low humidity elevates the vapour pressure deficit (Vanderkelen et al., 2018). A notable feature is the so-called "July paradox": despite being one of the coolest months, July often records high evaporation because strong Southeast Trade Winds enhance turbulent exchange and efficiently remove moisture from the lake surface.

Implications for Lake Levels

The near equilibrium between precipitation and evaporation makes Lake Victoria exceptionally sensitive to climatic anomalies. Even modest shifts—such as a 10% increase in rainfall—can produce multi-metre rises in lake level, as observed in 1961/62 and again in 2020. Conversely, rising temperatures are expected to increase PET by approximately 3.5 mm/decade, intensifying the basin's "evaporative tax" and potentially offsetting projected rainfall gains, with implications for long-term lake stability (Awange et al., 2008; Olaka et al., 2019).

4.1.5 Wind Regime

Geographic and Topographic Controls

The wind field over Lake Victoria cannot be understood without reference to its topography (Section 4.1.1). The lake sits in a shallow depression between the two arms of the East African Rift System: the Western (Albertine) Rift and the Eastern (Gregory) Rift. To the east, the Mau Escarpment and the Nandi Hills rise significantly, creating a physical barrier that channels the prevailing easterly trade winds (COWI, 2002; Nicholson, 1996). To the west,

the topography is more open but gradually rises toward the undulating hills of Rwanda and Uganda.

This orographic setting has two profound effects on the wind regime. First, the high terrain to the east acts as a mechanical obstacle, often decelerating the synoptic easterly flow or forcing it to divert around the highlands, creating zones of convergence and divergence that are critical for rainfall initiation (Anyah et al., 2006). Second, the temperature contrasts between the high-altitude land surfaces and the low-altitude lake surface (1,134 meters above sea level) amplify the thermal gradients that drive local wind circulations. The presence of the Nandi Hills specifically serves as a launchpad for katabatic (downslope) winds that accelerate onto the lake surface at night, reinforcing the land breeze and enhancing the convergence that triggers nocturnal thunderstorms (COWI, 2002; Woodhams et al., 2019).

Regional Trade Winds

Seasonal monsoon reversals set the background flow (Figure 4-6). The Southeast Trade Winds prevail from May to October, arriving as dry, stable air masses after crossing the Tanzanian plateau and reinforcing the long dry season (Nicholson, 2017). From November to March, the Northeast Trades take over, supplying the background easterly flow that supports the short rains when it encounters moist air from the west.

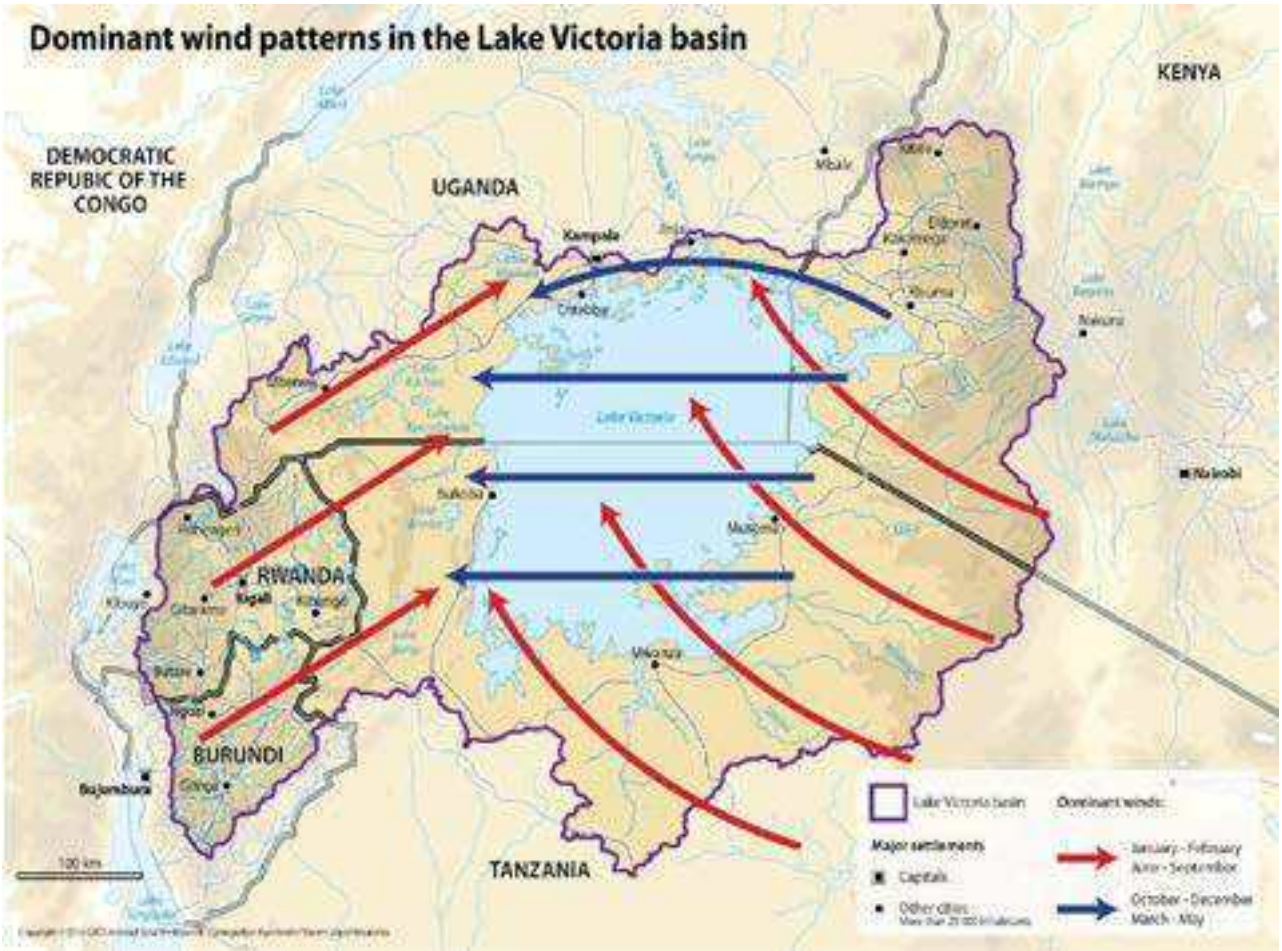


Figure 4-6. *Dominant wind patterns over the Lake Victori Basin (Grid-Arendal, 2017).*

The Congo Air Mass (Westerlies)

In addition to the dominant northeast and southeast trade winds, a third atmospheric system—the Congo Air Mass—plays a pivotal role in shaping rainfall over the Lake Victoria Basin. Originating over the dense rainforests of the Congo Basin to the west, this air mass is exceptionally moist and dynamically unstable. Where it converges with the easterly trade winds, it forms a distinct convergence zone commonly referred to as the Congo Air Boundary (CAB). When westerly flow strengthens and penetrates into the basin, it injects deep tropical moisture that triggers the most intense rainfall events. This process is especially evident during the transition seasons (MAM and OND), when seasonal wind fields frequently display westerly anomalies marking the episodic eastward advance of Congo air (Camberlin et al., 2018; Nicholson, 1996).

Lake–Land Breeze Circulation

Superimposed on the monsoons is a powerful diurnal solenoid circulation that governs daily convection. During the day, land heats more rapidly than the lake, producing a lake breeze that induces divergence and cloud clearing over the water and convergence over land, often triggering afternoon storms (Camberlin et al., 2018). At night, the circulation reverses: cooler air drains from land toward the warm lake, generating strong nocturnal convergence that forces deep convection and produces the basin's characteristic early-morning thunderstorms (Thiery et al., 2016).

Influence on Physical Limnology

Wind forcing is central to Lake Victoria's physical structure. Strong SE trade winds in June–July promote deep vertical mixing and periodic upwelling, supplying nutrients to the euphotic zone and temporarily breaking thermal stratification. Observed wind weakening has raised concerns about reduced mixing and the risk of more persistent deep-water anoxia (Nyamweya et al., 2016). Hazardous winds also arise when cold downdrafts from nocturnal storms interact with the warm lake surface, producing gusts exceeding 40–50 knots and waves of 2–3 m, a major safety risk for fishing communities (Thiery et al., 2016).

4.1.6 Relative Humidity and Atmospheric Moisture

Relative humidity (RH) across the Lake Victoria Basin is generally high but varies with proximity to the lake, seasonal moisture transport, and local thermal regimes.

The lake environment maintains persistently humid conditions, with mean annual RH typically 70–80%, while surrounding land areas show greater variability. The western sector remains consistently moist (>75%) due to frequent convergence of moist westerlies, whereas the eastern and southern semi-arid margins can fall to 50–60% during dry-season afternoons (LVBC, 2025). Basin humidity is shaped by the interaction of Atlantic-sourced westerlies and Indian Ocean easterlies, whose convergence along the Congo Air Boundary regulates moisture availability. Seasonal peaks occur during the MAM and SON rains, while January and July mark annual minima, though lake evaporation prevents extremely low RH values.

Humidity closely interacts with thermal conditions and evapotranspiration. High RH suppresses evaporative cooling, elevating heat stress for people and livestock, but simultaneously reduces atmospheric moisture demand, lowering PET in humid western zones. In contrast, the drier and hotter southeastern basin experiences the highest PET, where low humidity amplifies moisture deficits and intensifies drought vulnerability (Yin & Nicholson, 1998).

4.1.7 Solar Radiation and Sunshine Hours

The Lake Victoria Basin receives consistently high solar input owing to its equatorial position, with Global Horizontal Irradiance (GHI) ranging from 4.3 to 5.5 kWh/m²/day. Sunshine duration shows a clear west–east gradient: Kisumu records roughly 7.9 hours/day, while Entebbe averages about 6.6 hours/day. This contrast reflects greater daytime cloudiness in the western basin, where convergence between trade winds and land breezes enhances cloud formation, whereas the eastern sector experiences more frequent clearing as daytime winds diverge over the lake.

Satellite observations highlight a distinct diurnal "breathing" cycle in cloud cover. From 02:00 to 09:00 LST, deep nocturnal convection concentrates clouds over the lake (Thiery et al., 2016). As the lake breeze develops late in the morning, clouds dissipate over the water, and by afternoon (15:00–20:00 LST) convection intensifies over surrounding land, producing a characteristic ring of cloud around a relatively clear lake surface (Camberlin et al., 2018). This cycle shapes the basin's radiation balance by cooling land areas during the afternoon while maintaining elevated nighttime temperatures over the lake through cloud-mediated longwave trapping.

4.1.8 Historical Extreme Events

The Lake Victoria Basin's climate is marked by episodes of extreme rainfall and drought that have repeatedly reshaped its hydrology and exposed the vulnerability of communities and infrastructure.

Three major flood events dominate the basin's modern record. The 1961/62 "Uhuru Rains", driven by an exceptionally strong positive Indian Ocean Dipole (IOD), produced rainfall more than 300% above normal, raising lake levels by 2.5 m and permanently altering the shoreline (Nicholson, 2017). The 1997/98 El Niño triggered widespread flooding across East Africa. Most recently, the 2019/2020 positive IOD generated exceptional rainfall that lifted lake levels to 13.42 m at Jinja—surpassing the 1964 peak—and displaced more than 200,000 people, demonstrating the growing influence of ocean–atmosphere teleconnections on basin extremes (Thiery et al., 2021).

Major droughts—documented in 1967, 1980, 1983–84, 1990, 1993, early 1997, and 2004–2005—have likewise had significant hydrological impacts (Awange et al., 2008). The 2004–2005 event is especially notable: lake levels fell to historic lows, severely constraining hydropower at Owen Falls. Subsequent analyses showed that roughly half of the decline resulted from severe meteorological drought, while the remaining half stemmed from excessive water releases that exceeded the Agreed Curve, underscoring the combined role of climate variability and water management decisions (Vanderkelen et al., 2018).

4.1.9 Integration: Synthesis of Patterns and Future Outlook

Climate Zones Synthesis

The combined temperature, rainfall, and circulation patterns of the Lake Victoria Basin reveal four broad hydro-climatic zones. The lake proper forms a modified equatorial regime with high rainfall (>1,600 mm), low diurnal temperature range, and a dominant nocturnal convection cycle. The western littoral zone receives the basin's heaviest rainfall (>2,000 mm) due to persistent trade-wind convergence and therefore maintains low drought risk. In contrast, the eastern and southern semi-arid margins sit in a rain shadow, with <900 mm of rainfall, high PET, and strong climate variability. The elevated highland zone (Mau, Elgon, and the Rwandan uplands) is cooler, influenced by orographic and frontal precipitation, and plays a key role in sustaining baseflows (Beck et al., 2018).

Future Outlook and Hazards

Projected warming of 1.5–2.5°C by 2050 will increase PET and intensify evaporative losses from the lake (Olaka et al., 2019). Evidence also suggests that the long-standing "East African paradox" is shifting toward a wetter climate, with rainfall increases expected mainly during the Short Rains (SON). These gains, however, are likely to occur as more intense and hazardous events rather than as steady agricultural rainfall (Nicholson, 2017; Thiery et al., 2021). Ecologically, continued lake-surface warming is strengthening stratification, limiting deep-water oxygenation and narrowing viable habitat for species such as Nile perch, while amplifying eutrophication risks (Nyamweya et al., 2016). These trends are discussed in more detail in Chapter 5 (Water Quality) ad Chapter 7 (Climate Change).

4.2 Surface Water Resources and Hydrology

Surface water resources underpin the Lake Victoria Basin's water security, ecosystems, energy generation, and regional livelihoods. Section 4.2 examines the basin's river systems and 23 sub-basins, their runoff contributions and seasonal flow behaviour, and the contrasting hydrological regimes revealed by hydrographs and flow-duration curves. It also profiles the main inflow rivers, explains the lake's water balance and historical level dynamics, and critically assesses the effectiveness and constraints of outflow regulation under the Agreed Curve.

4.2.1 Major River Systems

The surface water hydrology of the Lake Victoria Basin is defined by a centripetal drainage system where a network of over 23 distinct rivers drains a catchment area of approximately 193,000 km². These rivers converge into the shallow depression of Lake Victoria, which acts as the hydrological heart of the system. While the direct rainfall onto the lake surface is the dominant volumetric input, the tributary rivers are the ecological and geomorphological lifelines of the basin, transporting the sediments, nutrients, and pollutants that define the lake's health. They also serve as the primary water sources for the millions of people living in the upper catchments who have no direct access to the lake itself (NBI, 2016; COWI, 2002).

The 23 Sub-Basins of the Lake Victoria Basin

The basin is hydrologically divided into 23 major sub-basins that vary in size, location, and hydrological contribution. (Figure 4-7).

> "Projected warming of 1.5–2.5°C by 2050 will increase PET and intensify evaporative losses from the lake (Olaka et al., 2019)"

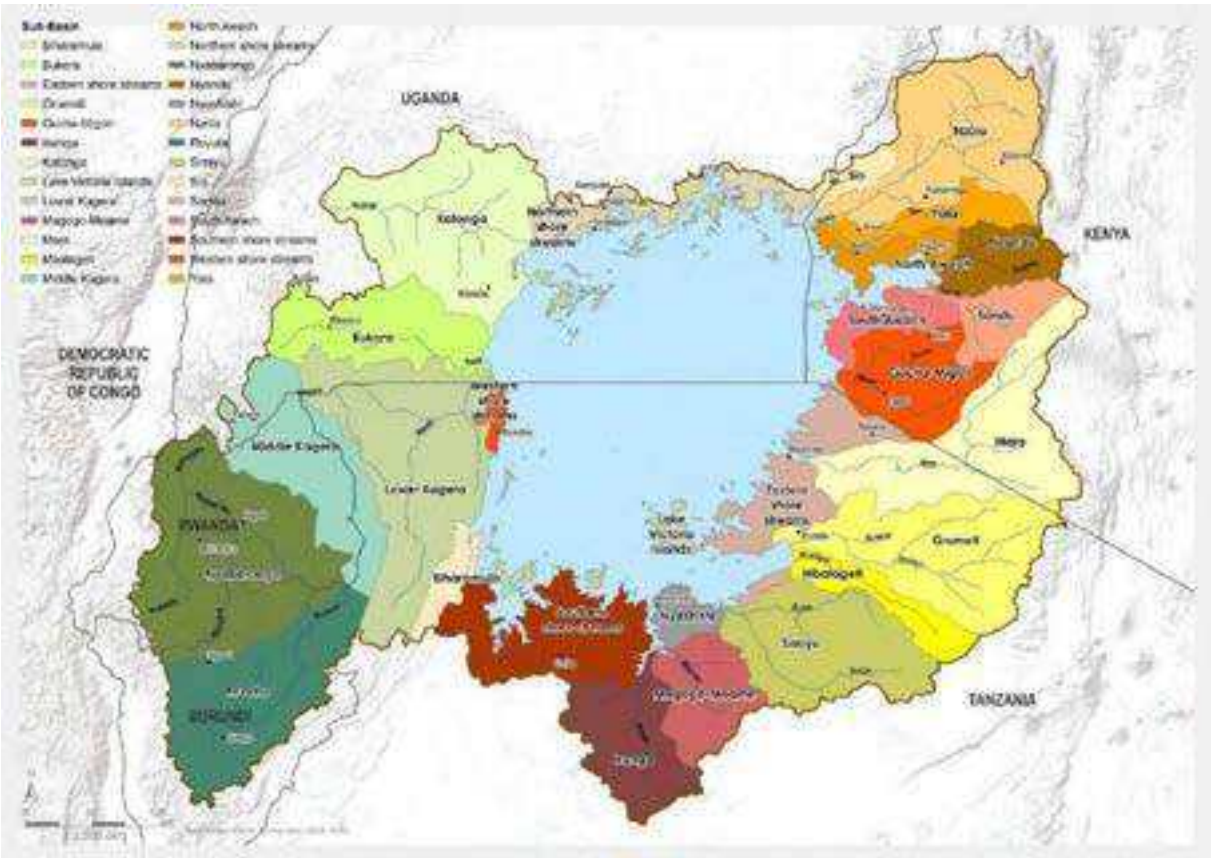


Figure 4-7. *The major sub-basins of the Lake Victoria Basin.*

The terrestrial basin is characterized by a high degree of topographic and geological diversity, which dictates the hydrological response of the 23 sub-catchments. The basin rises from the lake level (1,134 m a.s.l.) to altitudes exceeding 4,000 m a.s.l. in the volcanic highlands of Mount Elgon and the Virunga Mountains. The catchments can be grouped into three distinct ctagories.

- **Northern and Western Catchments (Uganda/ Rwanda/Burundi):** Dominated by steep, volcanic terrain with high drainage density. The soils here are generally deep and fertile (ferralsols/nitisols), but the steep slopes make them prone to rapid runoff and soil erosion if vegetation cover is compromised. The hydrological response is buffered somewhat by extensive wetland systems (e.g., Kagera swamps) which attenuate flood peaks (Nile Equatorial Lakes Subsidiary Action Program, 2012; FAO, 2011).
- **Eastern Catchments (Kenya):** Defined by the steep escarpments of the Rift Valley (Mau, Nandi, Cherangany). These rivers (Nzoia, Yala, Sondu) have high stream power in their upper reaches, facilitating hydropower generation, but transition into flat, alluvial plains (Kano, Budalangi) near the lakeshore, where they are prone to meandering and extensive flooding (Water Resources Authority, 2011; JICA, 2011).
- **Southern Catchments (Tanzania):** Characterized by gently undulating plains and plateau landscapes. The soils include expansive clays (vertisols) which have low infiltration rates when wet, leading to flashy runoff responses despite the lower rainfall totals. The lower gradient results in the formation of large seasonal wetlands and floodplains (e.g., Mara wetlands) (Rwetabula et al., 2007).

The key morphological and hydrological features of the 23 sub-basins are summarized in **Table 4-3** and **Figures 4-8 and 4-9).**

Table 4-3. Morphological features and estimates of local runoff in the LVB sub-basins (based on available data over the period 2002-2020)

No	Sub-Basin	Location With-in Basin	Catchment Area (km²)	Mean Annual Precipitation (mm)	Specific Runoff (mm)	Share of total riverine input (%)
1	Kagera	Southwest to West	55,618	1,129	236	31.9
2	Biharamulo	Southwest	1,785	1,193	285	2.1
3	Western Shore Streams	West	752	1,791	300	2.5
4	Katonga	West	13,922	1,109	10	0.6
5	Rwizi/Bukora	West	8,064	1,149	11	0.4
6	Simiyu	South	11,402	911	111	4.8
7	Isanga	South	6,662	952	121	3.3
8	Southern Shore Streams	South	9,027	1,094	83	2.8
9	Magogo–Maome	South	5,718	919	53	1.1
10	Nyashishi	South	1,485	995	24	0.2
11	Mara	East	13,519	1,096	93	4.5
12	Eastern Shore Streams	East	5,846	1,102	88	2.3
13	Grumeti	East	12,767	887	25	1.3
14	Mbalageti	East	3,597	887	39	0.5
15	Nzoia	Northeast	12,733	1,521	279	13.9
16	Gucha–Migori	Northeast	7,250	1,445	302	8.1
17	Sondu-Miriu	Northeast	3,455	1,668	420	5.6
18	Yala	Northeast	3,241	1,678	353	4.4
19	Nyando	Northeast	3,902	1,494	260	3.6
20	Sio	Northeast	1,745	1,702	299	2
21	South Awach	Northeast	2,690	1,440	295	0.7
22	North Awach	Northeast	1,947	1,482	157	0.5
23	Northern Shore Streams	North	6,148	1,345	126	3.2

Data Sources

1. (Kenya Water Resource Authority, Aurecon, 2020a)
2. (Kenya Water Resource Authority, Aurecon, 2020b)
3. (Lake Victoria Basin Commission, COWI, 2002)
4. (Lake Victoria Basin Water Board, IHE, SWP, 2019)
5. (Tanzania Ministry of Water and Irrigation, Nippon Koei, 2018)
6. Burundi LVBTDA
7. (Rwanda Natural Resources Authority, 2015)
8. (Rwanda Ministry of Environment, 2018a)
9. (Rwanda Ministry of Environment, 2018b)
10. Study team lowered Revised NIMP 2018
11. Uganda Ministry of Water and Environment, DWRM, 2014)

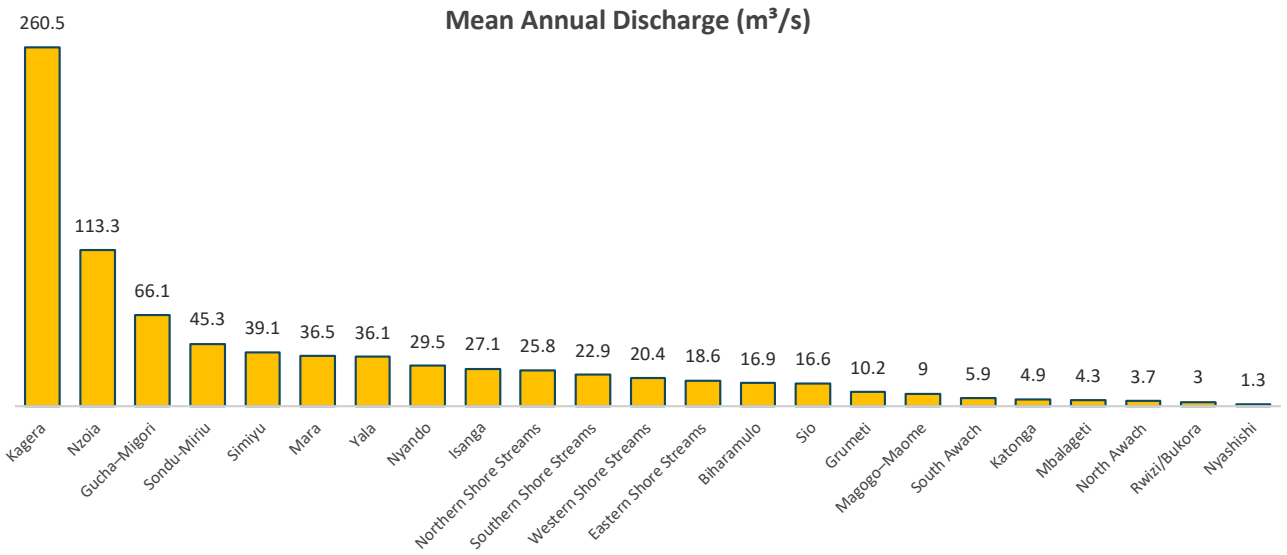


Figure 4-8. *Mean annual discharge of the LVB rivers basins (based on available data over the period 2002-2020)*

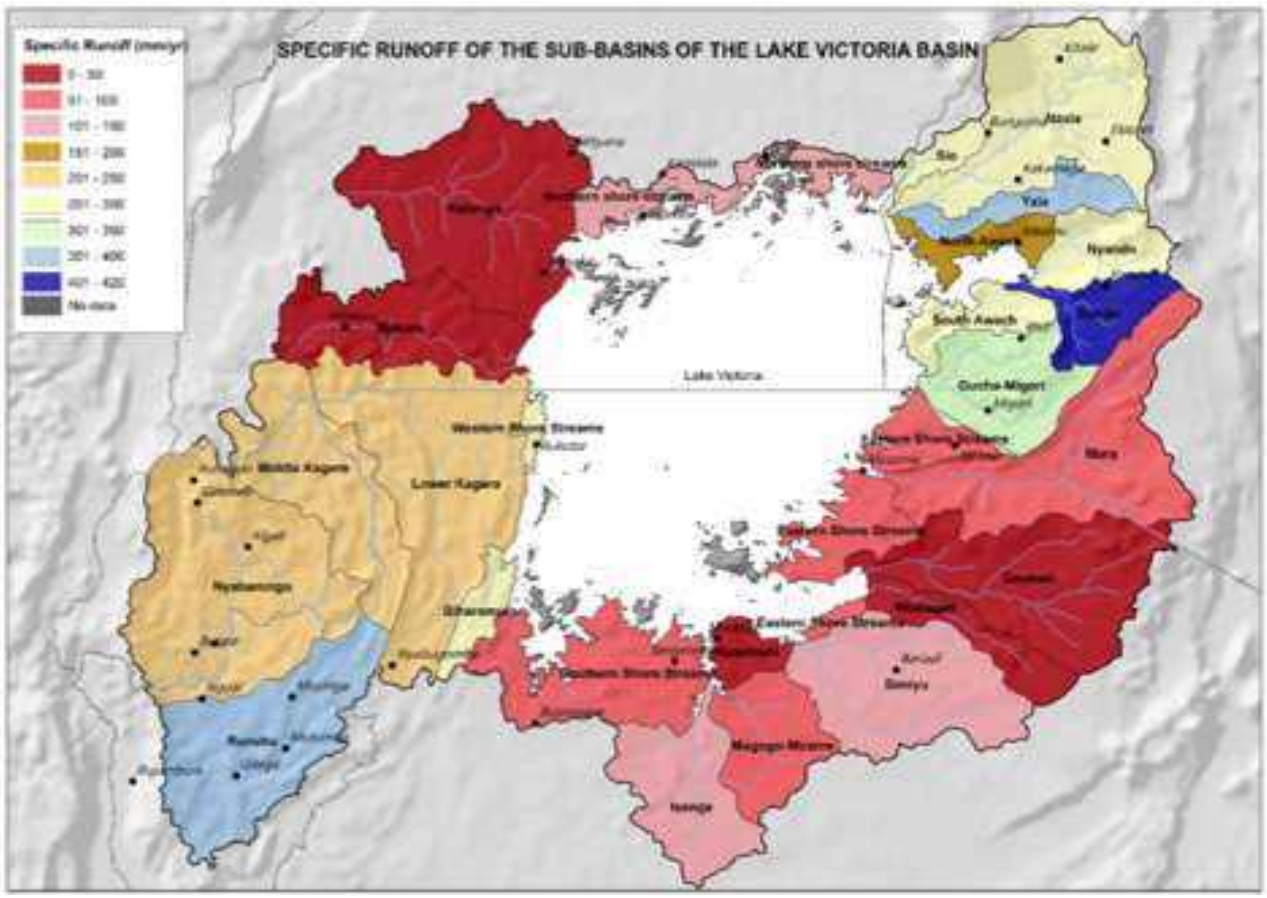


Figure 4-9. *Specific runoff of the LVB Sub-basins basins (based on available data over the period 2002-2020).*

The table and charts above show that, in addition to the Kagera, the rivers draining the northeastern Kenyan catchments make a major contribution to Lake Victoria's river inflows. Despite having the smallest share of the lake's open surface area, Kenya supplies about 45% of the lake's annual river inflow, underscoring the strategic importance of Kenyan watershed management for the overall health and stability of the lake.

4.2.2 Hydrographs and flow seasonality

The annual hydrographs of selected Lake Victoria Basin rivers **(Figure 4-10)** reveal a coherent basin-wide hydrological response that is fundamentally controlled by the region's bimodal rainfall regime, storage characteristics, and catchment scale. While all rivers exhibit seasonal variability linked to the short (OND) and long (MAM) rains, the magnitude of discharge, strength of baseflow, and sharpness of flood response vary systematically with catchment size, physiography, wetlands, and degree of regulation or abstraction. On this basis, the rivers can be grouped into three broad hydrological behaviour classes, each reflecting a distinct runoff–storage balance and flow reliability profile.

- **Large, Perennial, Rainfall-Integrated Rivers (High Baseflow, Moderate Seasonality):** Examples Kagera and is tributaries, Nzoia, Katonga. These rivers exhibit strong perennial flow with high dry-season baseflow, reflecting large catchment size, wet headwaters, and sustained groundwater contribution. Flows dip mildly during Jan–Mar and rise sharply during the long rains (Apr–May), with sustained high discharge into Jun–Aug, indicating basin storage buffering and slow runoff response.
- **Medium Catchments with Bimodal, Flashy Regimes (Strong Rainfall Control):** Examples: Mara, Yala, Gucha, Rwizi. These rivers show distinct bimodal seasonality, with peaks in Dec–Jan (OND/short rains) and Apr–May (MAM/long rains). Rapid rise and fall of flows indicates limited groundwater buffering and dominance of surface runoff, with pronounced dry-season lows in Feb–Mar and Jul–Aug.
- **Small or Regulated Catchments (Low Variability, Muted Peaks):** Examples: Ngono, Rwizi, Nyashishi. These rivers display narrow discharge ranges, subdued seasonality, and weak flood peaks, suggesting small contributing areas, strong regulation, wetland buffering, or abstraction effects. Peak flows still align with Apr–May, confirming rainfall control but with attenuated hydrological response.

Across all rivers, the dominant hydrological peak occurs in April–May, driven by the long rains, while secondary peaks in Nov–Jan reflect the short rains. Low-flow conditions are most persistent in Feb–Mar and Jul–Aug, marking key hydrological stress periods for water supply, ecosystems, and sediment transport.

> "....in addition to the Kagera, the rivers draining the northeastern Kenyan catchments make a major contribution to Lake Victoria's river inflows."

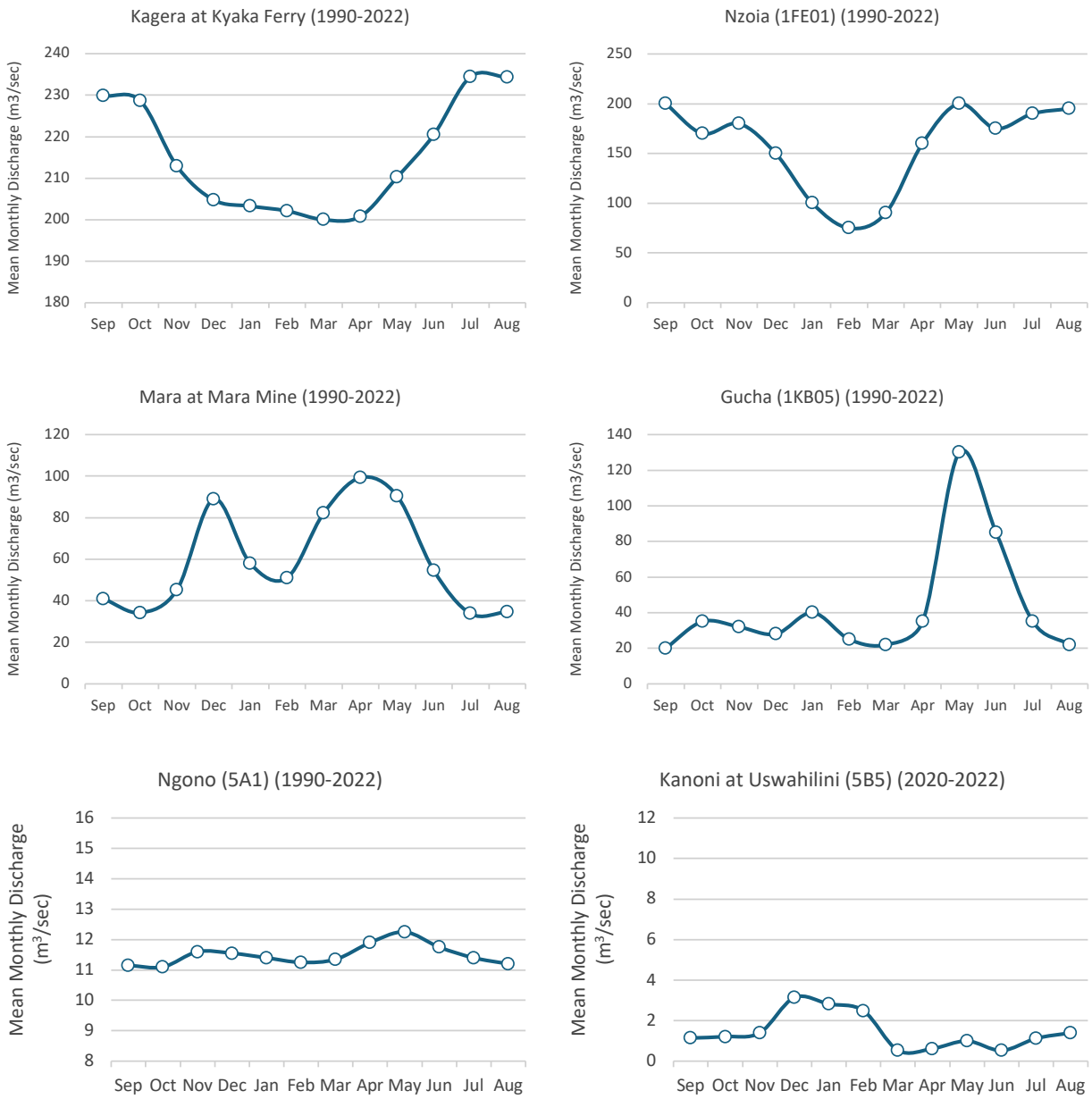


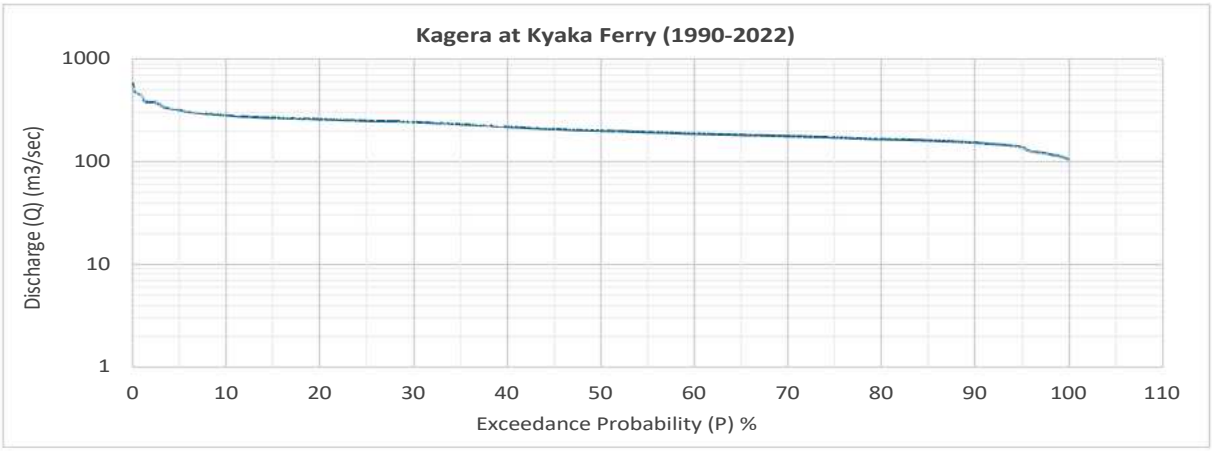
Figure 4-10. *Annual hydrographs of selected LVB rivers (source: National Hydrological Services of the Partner States).*

4.2.3 Flow Duration Curves (FDCs) and Low-Flow Characteristics

While the annual hydrographs (**Figure 4-10**) illustrate the seasonal timing and magnitude of flows, the flow duration curves provide a complementary perspective on flow reliability, drought resilience, and the persistence of low flows. By expressing the proportion of time that specific discharges are equalled or exceeded, FDCs distinguish between storage-regulated systems with stable baseflow and rainfall-dominated rivers characterised by extreme variability.

As shown in (Figure 4-11), the FDCs of the Kagera, Mara, and Simiyu rivers clearly mirror the three hydrological behaviour classes identified from the hydrograph analysis, but with sharper resolution of their contrasting low-flow and flood-flow dependencies.

- **Kagera River at Kyaka Ferry** – Highly Regulated, Storage-Dominated Regime: The Kagera's FDC is characteristically flat, confirming the strong buffering effect already evident in its hydrograph. The median discharge (Q50) is approximately 206 m³/s, while Q90 remains high at about 160 m³/s, and even extreme low flows (Q95) are sustained near 135 m³/s. The small separation between high- and low-exceedance flows reflects a system controlled by extensive upstream wetlands and headwater lakes, which dampen flood peaks and sustain dry-season flows. This behaviour underpins the Kagera's role as the most hydrologically reliable inflow to Lake Victoria, particularly during basin-wide drought periods.
- **Mara River at Mara Mine** – Flashy, Event-Driven Regime: Consistent with its bimodal and highly responsive hydrograph, the Mara exhibits a steep FDC slope, indicating strong contrast between low and high flows. The median discharge (Q50) is around 30 m³/s, while Q90 falls to approximately 5–8 m³/s, highlighting acute dry-season flow stress. At the upper end of the curve, the river is marked by extreme event flows, with documented floods exceeding 400 m³/s and a rank-1 discharge of roughly 1,073 m³/s in 2020. This wide dynamic range confirms the Mara as a runoff-dominated, flood-prone system, with high sensitivity to intense rainfall events and limited natural storage buffering.
- **Simiyu River at Mwanza–Musoma Bridge** – Semi-Arid, Highly Variable Regime: The Simiyu FDC represents the most hydrologically constrained end of the basin spectrum, reinforcing its classification as a seasonal to episodic system. Q95 values approach near-zero discharge in dry years, indicating prolonged periods of severely reduced flow. Although weak perennial flow is often maintained in the main channel, the headwaters frequently contract to ephemeral conditions. The very steep lower limb of the curve reflects exceptionally high inter-annual variability, with coefficients of variation commonly exceeding 1.0, making the Simiyu the least reliable river for sustained water supply and ecological support among the three.





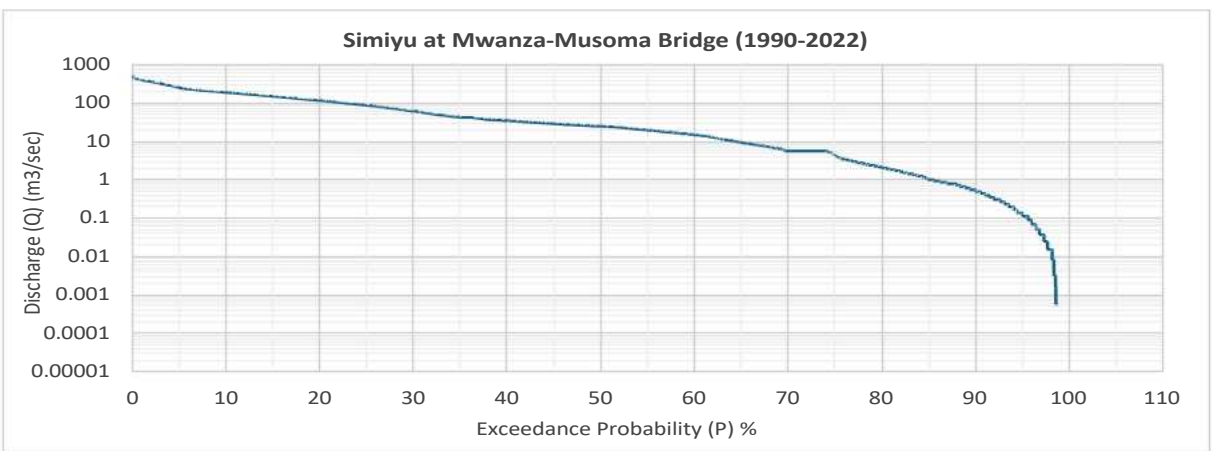


Figure 4-11. *Flow duration curves (1990–2022) for the Kagera, Mara and Simiyu Rivers, illustrating contrastin-ghydrological regimes—stable, storage-regulated flows in the Kagera; highly variable, flood-domi-nated behaviour in the Mara; and extreme low-flow vulnerability with near-episodic conditions in the semi-arid Simiyu. (Source: LVB National Hydrological Service of the LVB Partner States).*

4.2.4 Profile of main rivers

Building on the hydrograph and flow-duration curve analyses, this section succinctly profiles the six rivers that dominate terrestrial inflow to Lake Victoria—the Kagera, Nzoia, Mara, Yala, Nyando, and Simiyu. Together, they define the basin's hydrological spectrum, from highly buffered perennial systems to semi-arid, episodic rivers, and account for the overwhelming share of riverine inflow (COWI, 2002; NELSAP, 2012).

Kagera River Basin

The Kagera is the primary hydrological regulator of Lake Victoria, contributing about 33–34% of total inflow (COWI, 2002; NELSAP, 2012). Its 59,800 km² transboundary basin spans Rwanda, Burundi, Tanzania, and Uganda (NELSAP, 2012; FAO, 2011). Originating in the high-rainfall Rwindiniza and Burundi highlands, the Kagera flows for approximately 400 km along its main stem before discharging into Lake Victoria near Sango Bay. The river exhibits a storage-dominated regime, sustained by extensive upstream lakes and wetlands, and maintains a high mean discharge of 260–346 m³/s with limited dry-season contraction (COWI, 2002; NBI, 2016). However, it also delivers substantial sediment and nutrient loads, with recent isotope studies attributing 49–73% of nitrate loading to manure and sewage, posing eutrophication risks to near-shore waters (MDPI, 2025; Nduwayezu et al., 2025).

Nzoia River Basin

The Nzoia is the largest Kenyan tributary and the second-largest contributor to the lake (~15%) (COWI, 2002). Draining 12,800–12,900 km² from Mount Elgon and the Cherangany Hills, it is a permanent but highly responsive river (WRA, 2011; JICA, 2011). With a mean discharge of about 118 m³/s and annual runoff near 3,721 MCM, the Nzoia rapidly converts intense rainfall into flow, giving rise to chronic flooding in the Budalangi plains, where dyke protection is frequently overtopped under extreme events (Khan et al., 2011).

Mara River Basin

The Mara is a transboundary, ecologically critical river supporting the Serengeti–Mara ecosystem. Its 13,750 km² basin, shared between Kenya and Tanzania, drains the Mau Forest and discharges into Musoma Bay (Melesse et al., 2008). The river is strongly rainfall-dominated, with median flows near 30 m³/s, severe dry-season contraction, and extreme flood peaks exceeding 1,000 m³/s in recent records (GLOWS, 2007; Melesse et al., 2008). Land-use change in the Mau headwaters has intensified flow variability, weakening dry-season reliability and increasing flood risk.

Yala River Basin

The Yala drains about 3,351 km² of the Nandi Escarpment and flows ~219 km to Lake Victoria through the Yala Swamp (JICA, 2011). With a mean discharge of ~36.5 m³/s, it represents a medium-sized, rainfall-responsive system (WRA, 2011). The Yala Swamp provides critical flood moderation and water-quality buffering, functioning as one of the basin's most important natural nutrient and sediment filters, though increasing wetland conversion now threatens these regulatory services (JICA, 2011).

Nyando River Basin

Despite its modest size (~3,618 km²), the Nyando is the basin's most destructive sediment-yield system (JICA, 2011). The river is short (~153–170 km) with a mean discharge of 29.5 m³/s, yet produces disproportionately severe flooding in the Ahero–Kano plains (JICA, 2011; Onyutha et al., 2016). Rapid runoff from degraded hillslopes and extreme gully erosion generate the highest sediment yields per unit area in the Lake Victoria Basin, driving channel aggradation and chronic flood vulnerability.

Simiyu River Basin

The Simiyu drains approximately 10,800 km² of Tanzania's semi-arid southern basin and represents the basin's dryland hydrological extreme (Rwetabula et al., 2007). The river is seasonal to episodic, with dry-season flows

frequently approaching zero, but wet-season peaks exceeding 200 m³/s (Rwetabula et al., 2007; Mulungu & Munishi, 2007). Modelling confirms negligible groundwater contribution, as nearly 90% of rainfall is lost to evapotranspiration before deep recharge occurs (Rwetabula et al., 2007). As a result, the Simiyu is the least reliable river for dry-season supply and among the most climate-sensitive in the basin.

4.2.5 Lake Victoria Dynamics and Water Balance

The Water Balance Equation

The water balance of Lake Victoria is dominated by "vertical" fluxes (precipitation and evaporation) rather than "horizontal" fluxes (inflow and outflow). This distinguishes it from most other major lakes where riverine input is dominant. The balance can be expressed as:

$$\Delta S = (P + Q_{in}) - (E + Q_{out}) \pm \varepsilon$$

Where:

- P = Precipitation over the lake surface (input)
- Q_{in} = Catchment inflow from tributaries (input)
- E = Evaporation from the lake surface (output)
- Q_{out} = Discharge at the lake outlet in Jinja (output)
- ε = Error term (accounting for groundwater interaction and measurement uncertainties)

The above components are summarized in the Figure 4-12 below.

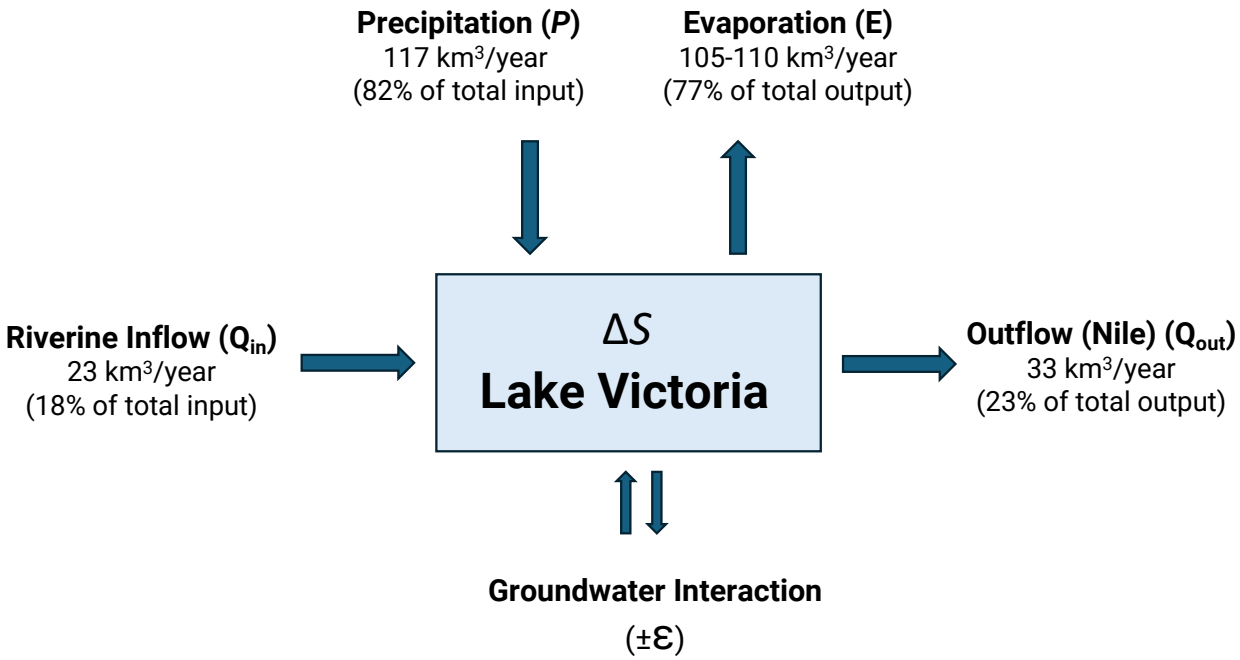


Figure 4-12. Lake Victoria Basin Annual Water Balance Components. (Source Data: Synthesized from COWI (2002); Sutcliffe & Parks (1999); NBI (2016). Note: Imbalances result in level changes)

Key components analysis

1. **Precipitation (*P*):** Rainfall directly onto the lake surface is the primary input, accounting for 80–82% of the total water supply. This amounts to approximately 117 km³/year (averaging ~1,600–1,700 mm/year). The mesoscale convection systems (discussed in 4.1) ensure that the lake receives significantly more water than its catchment (COWI, 2002; Yin & Nicholson, 1998).
2. **Evaporation (*E*):** Evaporation is the dominant loss factor, removing 76–80% of the water (approx. 105–110 km³/year). This massive flux is driven by the tropical solar radiation and wind speed over the fetch of the lake. Crucially, *P and E are of similar magnitude, meaning the lake exists in a precarious hydrological balance (Vanderkelen et al., 2018; COWI, 2002).*
3. **Tributary Inflow (Q_{in}):** River discharges contribute only 18–20% of total input, amounting to roughly 23 km³/year. While volumetrically secondary, this component is the primary driver of inter-annual variability in the Net Basin Supply (NBS) due to the flashy nature of the rivers compared to the relatively stable lake rainfall (COWI, 2002; Sutcliffe & Parks, 1999).
4. **Outflow (Q_{out}):** The Victoria Nile at Jinja is the sole surface outlet, accounting for 20–24% of output (approx. 33 km³/year). Historically, this outflow was naturally controlled by the Ripon Falls. Since 1954, it has been regulated by the Nalubaale and Kiira hydropower dams following the agreed curve (COWI, 2002; Sutcliffe & Petersen, 2007).

The above components are summarized in the table below.

Table 4-4. Annual Water Balance Components

Location/ Zone	Annual Volume (km³)	% of Total Input/Output
INPUTS		
Precipitation on Lake (*P*)	~117	~82%
Basin Inflow (Q_{in})	~23	~18%
Total Input	***~140***	***100%***
OUTPUTS		
Evaporation (*E*)	~105 - 110	~77%
Outflow (Nile) (Q_{out})	~33	~23%
Total Output	***~138 - 143***	***100%***

Source Data: *Synthesized from COWI (2002); Sutcliffe & Parks (1999); NBI (2016). Note: Imbalances result in level changes.*

Lake Morphometry and Residence Times

Lake Victoria occupies a shallow tectonic depression with relatively uniform bathymetry compared to the deep Rift lakes, but with locally complex littoral hydrodynamics shaped by major islands (Ssese, Buvuma, Ukerewe) and embayments (Winam, Murchison) (NBI, 2016). Its hydraulic residence time of ~21–23 years and exceptionally long flushing time of ~138 years impose a fundamental management constraint: pollutants entering the lake persist for decades and accumulate in sediments and the food web, underscoring the critical importance of stringent catchment pollution control (COWI, 2002; Sutcliffe & Parks, 1999).

Historical Level Fluctuations and the "Uhuru Rains"

The Lake Victoria level record since 1896 reveals alternating phases of relative stability and abrupt climate-driven regime shifts. The most profound transition occurred during the 1961/62 "Uhuru Rains", when an extreme positive Indian Ocean Dipole triggered a rapid 2.5 m rise in less than two years, permanently raising the lake's baseline and requiring recalibration of the outflow curve (Kite, 1981; Sutcliffe & Petersen, 2007). By contrast, the 2000–2006 drawdown to near-historic lows has been attributed roughly equally to severe drought and over-abstraction at the Jinja dams (Sutcliffe & Petersen, 2007; Kull, 2006). More recently, the 2019–2020 high-water event, which exceeded the 1960s record, reaffirmed the lake's extreme sensitivity to climate anomalies, with climate change estimated to have increased the likelihood of the event by 1.8 times through intensified IOD-related rainfall (Kimutai et al., 2024; NBI, 2024).

> "Hydrological research confirms that wholesale abandonment of the Agreed Curve would be destabilizing: managing for constant lake levels or constant hydropower output drives unsustainable lake-level drift and amplifies long-term risk (Vanderkelen et al., 2018)."

4.2.6 Outflow Regulation: The Agreed Curve Debate

The **Agreed Curve**, established in the 1950s to mimic natural outflows from Lake Victoria while safeguarding downstream irrigation in Egypt, has become increasingly misaligned with contemporary hydrological extremes, regional development needs, and principles of equitable transboundary water governance. Originally grounded in historical lake level–discharge observations at Ripon Falls, the policy reflected a colonial hydraulic objective: guaranteeing dry-season flows for Egyptian cotton irrigation through control of the White Nile (International Water Law Project, 1929; United Nations, 1959). While scientifically robust for its time, the framework now constrains Uganda's hydropower optimization, marginalizes upstream states, and lacks the flexibility required under accelerating climate variability.

For over four decades after commissioning of the Owen Falls/Nalubaale complex in 1954, the system operated with relative stability, maintaining lake levels around long-term means while supporting downstream flows and regional electricity supply. This equilibrium fractured between 2000 and 2006 when hydropower expansion at Kiira coincided with drought. Empirical reconstruction shows that approximately half of the 0.69 m lake level decline during this period was attributable to releases exceeding the Agreed Curve, with the remainder driven by climatic deficit (Vanderkelen et al., 2022). The episode exposed structural weaknesses: lack of compliance enforcement,

absence of a basin-wide abstraction framework, and the exclusion of Kenya and Tanzania from operational decision-making despite bearing navigation, water supply, and fisheries impacts.

The limitations of the Agreed Curve have become still more evident under recent climate extremes. Exceptional basin-wide rainfall in 2019–2020 and 2023-2024 drove lake levels to their highest point since 1964, a rise that attribution studies identify as significantly intensified by anthropogenic climate change (Copernicus, 2024; Vanderkelen et al., 2024). Uganda released up to ~2,400–2,600 m³/s, far beyond the Curve's intended operating range, yet inflows still outpaced discharge capacity. Flooding displaced hundreds of thousands across the Lake Victoria littoral and propagated downstream into Lakes Kyoga, Albert, and the Sudd wetlands of South Sudan, where over 900,000 people were affected by 2024 in what is now considered a case of climate-driven long-term displacement (University of Reading, 2024; The Watchers, 2024). These events exposed a fundamental design constraint: the Nalubaale–Kiira outlet cannot safely convey extreme inflows without simultaneously amplifying downstream flood risk.

Following the 2006 crisis, the Lake Victoria Basin Commission (LVBC) initiated the development of a New Water Release and Abstraction Policy (2007–2012). The technically advanced proposal sought to optimize lake storage for multiple objectives and incorporate abstraction controls across the basin. However, it failed to secure political adoption and remains non-binding to date (Vanderkelen et al., 2022). Uganda objected on three principal grounds: inadequate accommodation of integrated hydropower cascade optimization, failure to regulate rapidly growing upstream abstractions, and continued asymmetry whereby outlet regulation fell disproportionately on Uganda while upstream withdrawals remained weakly governed. As a result, operational practice continues to default to the colonial-era curve, supplemented only by ad hoc crisis management.

The persistence of the Agreed Curve is inseparable from wider Nile Basin politics. The 1929 and 1959 Nile agreements allocated the entirety of measured Nile flows to Egypt and Sudan, embedding downstream hydro-hegemony and excluding upstream states from formal quantitative rights (International Water Law Project, 1929; United Nations, 1959; Brookings, 2020). While the Cooperative Framework Agreement (CFA) entered into force in October 2024 after ratification by six upstream countries, Egypt and Sudan remain outside this framework, leaving parallel and incompatible governance regimes in place (International Water Law Project, 2024). In this fractured setting, the Agreed Curve continues to operationalize historical downstream guarantees while lacking legitimacy among upstream riparians.

Hydrological research confirms that wholesale abandonment of the Agreed Curve would be destabilizing: managing for constant lake levels or constant hydropower output drives unsustainable lake-level drift and amplifies long-term risk (Vanderkelen et al., 2018). The Curve's core ecological principle—allowing natural variability—remains valid. The challenge is therefore modernization, not replacement. Future management must embed the Curve within an adaptive, forecast-informed operating framework, with differentiated rules for normal, drought, flood, and extreme conditions, supported by seasonal climate prediction and real-time basin monitoring (UCSD, 2024; Copernicus, 2024).

In summary, the Agreed Curve is both hydrologically necessary and politically obsolete in its current form. It has failed under both drought stress (2000–2006) and extreme flooding (2019–2024), while perpetuating colonial-era inequities in Nile water governance. The pathway forward lies in climate-adaptive operations, basin-wide abstraction accounting, benefit-sharing, and strengthened regional institutions, aligned with the emerging CFA architecture. Without these reforms, Lake Victoria will remain a focal point of intensifying climate risk, geopolitical tension, and uneven development across the Nile Basin.

4.3 Groundwater Resources

Groundwater is a strategic pillar of water security in the Lake Victoria Basin, sustaining rural water supply, moderating hydrological extremes, supporting river baseflows, and enabling agricultural, industrial, and urban development. **Section 4.3** synthesizes the basin's geological and tectonic controls, recharge processes, and hydrogeological domains, and evaluates aquifer productivity, vulnerability, and spatial variability. It further presents sub-basin snapshots, groundwater–surface water interactions, sectoral uses, the role of transboundary aquifers, and the persistent gaps in groundwater monitoring and governance.

4.3.1 Geological and Tectonic Framework

Groundwater in the LVB exists in a state of paradox. It is ubiquitous yet unevenly distributed; it is renewable yet fragile. The hydrogeological potential of the LVB is fundamentally determined by its geological evolution, which is tied to the genesis of the East African Rift System (EARS) and the stability of the Tanzania Craton. The interaction between these tectonic features has created distinct aquifer environments (Ligate et al., 2021).

Weathered Precambrian Basement Aquifers

The central part of the basin, particularly south and west of the lake in Tanzania, Uganda, and parts of Kenya, is underlain by the Archean Tanzania Craton and surrounding Proterozoic mobile belts (Ligate et al., 2021). These formations are dominated by hard, crystalline rocks such as granites, gneisses, and schists, which possess negligible primary porosity and have remained tectonically stable for billions of years. As a result, groundwater storage and movement are controlled entirely by secondary porosity developed through prolonged weathering and tectonic fracturing. Weathering produces a regolith or saprolite layer, typically 20–50 m thick, which serves as the principal storage reservoir, while the underlying fractured bedrock provides pathways for groundwater transmission. Together, these form a composite aquifer system characteristic of Precambrian basement terrains (Taylor & Howard, 2000; BGS, 2000).

Tertiary Volcanic Aquifer Systems

Surrounding this stable core are the mobile belts and Cenozoic volcanic formations associated with the Gregory Rift create complex. These formations, which include phonolites, trachytes, basalts, and pyroclastics (NBI, 2022a), are located to the east in Kenya and to the north around Mt. Elgon on the Uganda–Kenya border. These occur as layered lava flows interbedded with paleosols and pyroclastic deposits, forming complex, multi-layered aquifer systems (Ligate et al., 2021). Groundwater storage and transmission are controlled by permeability contrasts between successive lava flows and by dense fracture networks, with highly transmissive zones commonly developing along flow contacts. The Mt. Elgon system functions as a radial groundwater drainage system, transmitting recharge from the high-rainfall caldera to surrounding lowland plains.

Quaternary Alluvial and Lacustrine Aquifer Systems

The low-lying floodplains of the major rivers—including the Kagera, Nzoia, Nyando, and Yala—and the lacustrine margins of Lake Victoria are underlain by thick sequences of Quaternary alluvial and lacustrine sediments (Vanderkelen et al., 2018). These deposits consist mainly of unconsolidated sands, gravels, silts, and clays, which collectively form the most productive aquifer systems in the basin in terms of both groundwater storage and transmissivity. These are typically shallow, unconfined, and highly

susceptible to interaction with surface water, making them both productive and vulnerable to contamination. Among these systems, the Kagera aquifer, developed within alluvial deposits of the river valley, is the most extensive and hydrogeologically significant (NBI, 2025).

The above three geological domains fundamentally determine groundwater storage, productivity, recharge potential, and vulnerability to contamination in the LVB, with no laterally continuous basin-wide aquifer system present (UNEP, 2006; BGS, 2023).

4.3.2 Recharge mechanisms

Recharge in the basin is rainfall-driven but strongly constrained by soil properties, geological structure, and river connectivity. Direct infiltration dominates in volcanic and sandy terrains (Figure 4-13), but is severely limited in clay-rich basement regoliths, where recharge typically remains below 100 mm/year (Mukwaya et al., 2024). As a result, preferential flow along fractures and lineaments becomes the primary recharge pathway in basement and volcanic terrains, generating highly localized but potentially high recharge zones (IGAD, 2022). In alluvial systems—especially the Kagera corridor—recharge is largely controlled by river-bank infiltration, estimated at 40–50 MCM/year, directly tying groundwater sustainability to surface flow regimes and wetland integrity (NBI, 2025b).

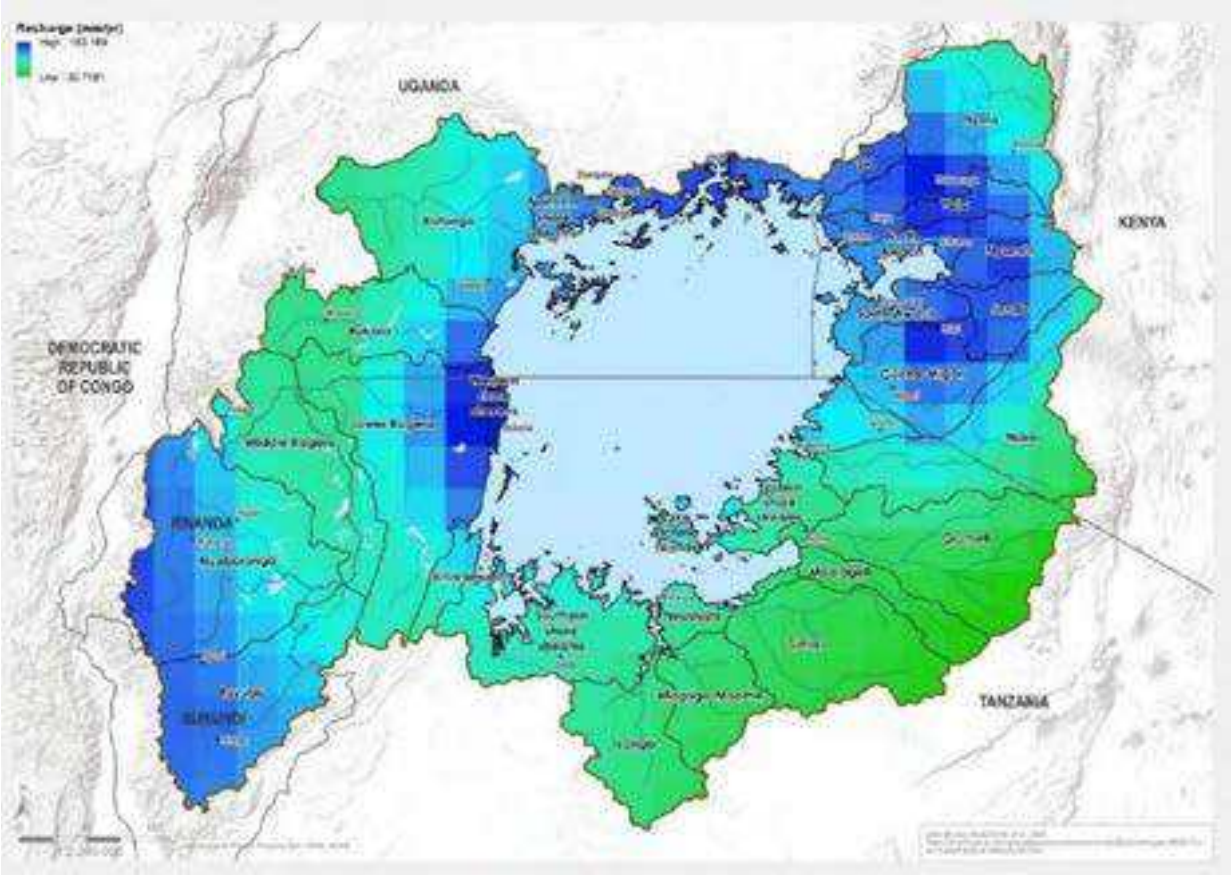


Figure 4-13. *Groundwater recharge (mm/yr) (MacDonald, et al., 2021)*

These structural controls on hydraulic performance are reflected in the mapped spatial distribution of groundwater productivity across the basin, where the highest yields are concentrated in volcanic and alluvial corridors, and the lowest yields dominate the basement-dominated interiors (**Figure 4-14**).

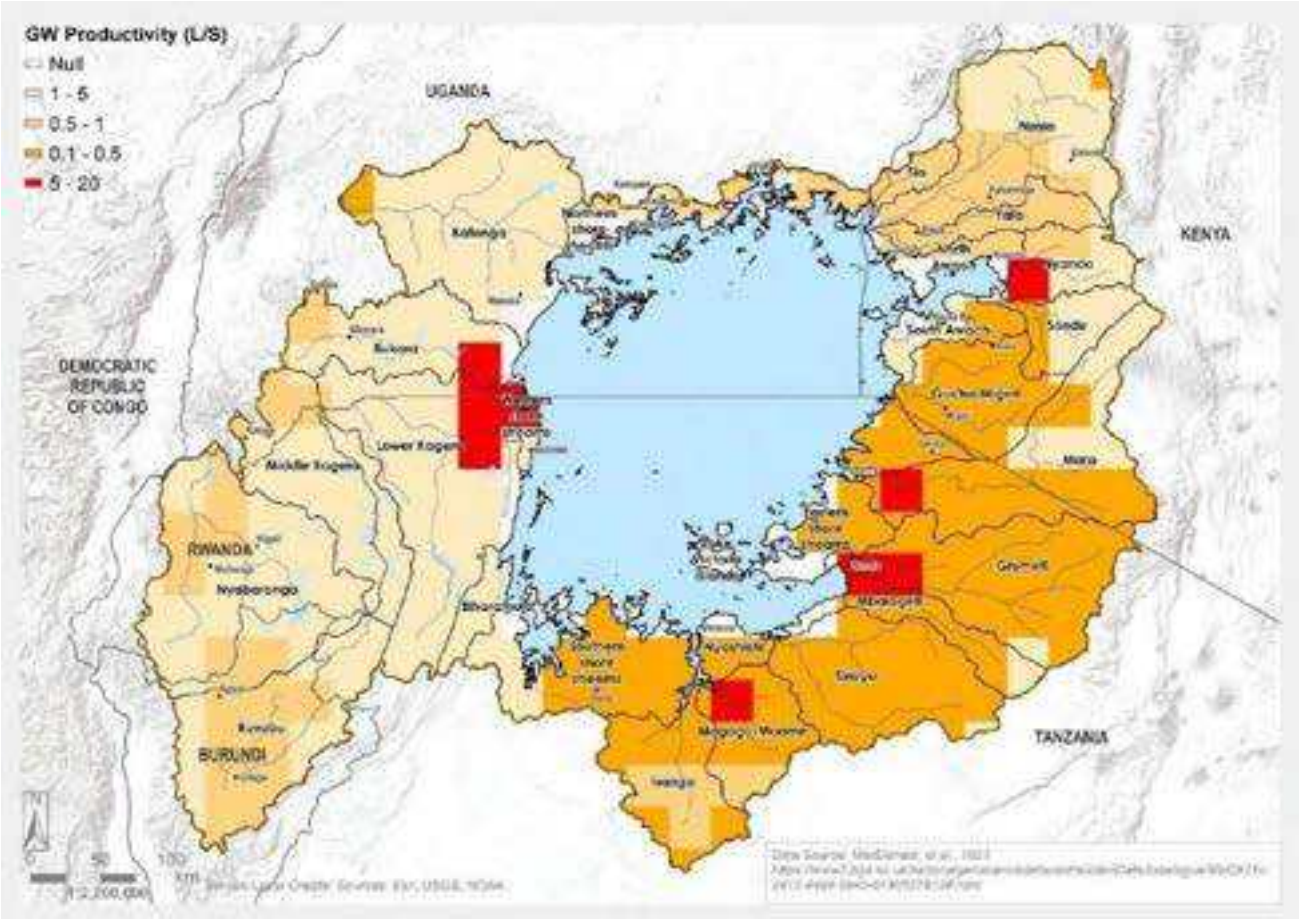


Figure 4-14. *Spatial distribution of groundwater productivity (L/s) in the Lake Victoria Basin (MacDonald, et al., 2021*

4.3.3 Hydrogeological Domains and Hydraulic Characteristics

A granular understanding of groundwater potential requires analyzing the specific hydraulic properties—Transmissivity (T), Hydraulic Conductivity (K), and Storativity (S)—of the basin's distinct hydrogeological domains. These properties, which control groundwater storage, movement, and well productivity across the Lake Victoria Basin, are summarized comparatively in **Table 4-5.**

The Weathered Basement (Regolith-Fracture) System

This is the most spatially extensive aquifer type, covering vast swathes of Uganda, Tanzania, and western Kenya (BGS, 2000). This system supports the majority of the rural population but is often the least understood in terms of bulk storage. This composite aquifer system typically consists of two hydraulic layers (BGS, 2000):

The Regolith (Saprolite): A shallow layer of weathered rock material, ranging from clay-rich to sandy depending on the parent rock and degree of weathering. It typically has high porosity (storage capacity) but low permeability.

The Fractured Bedrock: The underlying fresh rock, where groundwater flows through faults, joints, and fractures. It has low porosity but higher permeability.

The productivity of a borehole in this system depends on the connectivity between these two layers. The regolith acts as a reservoir that slowly feeds water into the fracture network, which acts as a conduit to the well. If the regolith is too thin or composed of impermeable clay, the borehole may have a high initial yield that rapidly declines as the fractures drain without replenishment (IWMI, 2018).

- **Hydraulic Properties:** The system is characterized by pervasive low permeability. Median transmissivity (T) is consistently <1.0 m2 /day (typically 0.7 – 0.9 m²/day) (Owor et al., 2022).
- **Yields:** Borehole yields are typically low, averaging 0.5 – 3.0 m3/hr (Ministry of Water Tanzania, 2019). These yields are sufficient for hand pumps (which require ~0.8 m3/hr) but are often inadequate for motorized schemes or irrigation.
- **Storage Dynamics:** The aquifer has low storage capacity. During prolonged dry seasons, the water table may drop into the fractured bedrock, causing the borehole yield to decline sharply as the storage in the regolith is exhausted.
- **Permeability:** Fractured zones show hydraulic conductivity (K) of approx 0.017 m/day, while the matrix is essentially impermeable (10-7 m/day) (Owor et al., 2022).

The Volcanic Aquifers (Rift Flanks)

Concentrated in the Mt. Elgon and Mau Complex regions, these aquifers represent the basin's "strategic reserves".

These aquifers are found in the Mt. Elgon region, the Mau Forest Complex, and the Kisii Highlands. They consist of alternating layers of lava flows (phonolites, trachytes, basalts) and pyroclastic deposits (tuffs, agglomerates). Paleosols—ancient soil layers buried by subsequent lava flows—often act as aquitards or confining layers, creating complex multi-layered systems (Nair et al., 2024).

- **Hydraulic Properties:** Volcanic aquifers are among the highest-yielding in East Africa but exhibit extreme heterogeneity. While mean transmissivity is estimated at 9.7 m2/day, localized fracture zones can exceed 100 m2/day (NBI, 2022a). This high diffusivity means the aquifers can transmit recharge rapidly from high elevations to the lowlands.
- **Yields:** Boreholes yields can exceed 20 m3/hr, making them suitable for small-town water supplies (NBI, 2022a). The Kisii Volcanics is characterized by highly productive aquifers supporting one of the highest rural population densities in Africa. Springs are common and high-yielding (Olago, 2019).
- **Vulnerability:** The high fracture permeability facilitates rapid recharge but also rapid contaminant transport. The dissolution of fluoride-bearing minerals in volcanic rocks can lead to groundwater fluoride concentrations exceeding 5–10 mg/L, well above the WHO guideline of 1.5 mg/L, causing dental and skeletal fluorosis in dependent populations (Nair et al., 2024; Ligate et al., 2021).

Alluvial and Lacustrine Systems

These aquifers are located in the low-lying floodplains of the major rivers (Kagera, Nzoia, Yala, Nyando) and the wetlands fringing Lake Victoria (NBI, 2025).

Alluvial aquifers are characterized by high primary porosity and permeability, consisting of sands, gravels, and silts. They are in direct hydraulic continuity with surface water bodies (Vanderkelen et al., 2018). During the wet season, river stages rise, and water flows into the aquifer (bank storage). During the dry season, the hydraulic gradient reverses, and groundwater discharges into the river, maintaining baseflow.

This interaction is critical for the ecological health of the basin's wetlands (Sutcliffe & Petersen, 2007).

- **Kagera Aquifer (High Potential):** Located in the Kagera river valley, this aquifer consists of coarse sands and gravels. Mean transmissivity is very high at 129 m2/day, with hydraulic conductivity (K) averaging 5.6 m/day (Ozan et al., 2018). This indicates a system capable of supporting high-capacity wells for irrigation.
- **Kano Plains (Low Potential):** Although sedimentary, the Kano Plains (Kenya) are dominated by lacustrine clays. Transmissivity is low (<10 m2/day), and the dominance of clays creates issues with salinity and waterlogging (Kanoti et al., 2020).
- **Vulnerability:** Because these aquifers are shallow (water tables often <5m) and unconfined, they are extremely vulnerable to surface contamination (Barigye et al., 2024). Agricultural runoff containing nitrates and pesticides, as well as biological pathogens from sanitation facilities, can rapidly infiltrate these systems. Additionally, they are sensitive to evaporation and development of salinity as observed in the Kano Plains of Kenya (Ministry of Water Kenya, 2020).

Table 4-5. Comparative Hydraulic Properties of LVB Aquifers.

Aquifer Domain	Primary Lithology	Median Transmissivity (T)	Typical Yield	Primary Constraint
Basement Complex	Granite/Gneiss Regolith	< 1.0 m^2/day	0.5 – 3.0 m^3/hr	Low permeability; limited storage
Volcanic (Rift)	Basalt/Phonolite Fractures	2.4 - 100 m^2/day	5 – 20+ m^3/hr	Fluoride contamination; depth
Kagera Alluvial	Sands/Gravels	129 m^2/day	> 20 m^3/hr	Vulnerability to pollution
Kano Lacustrine	Clay/Silt/Sand	0.1 – 9.0 m^2/day	Variable	Salinity; low permeability

Source: *Synthesized from NBI (2025); Ozan et al. (2018); Owor et al. (2022); Kanoti et al. (2020).*

4.3.4 Sub-Basin Snapshots

A comparative summary of renewable groundwater resources, safe yields, and dominant aquifer types across the major sub-basins is provided in Table 4-4.

Kenya: The Water Towers and Lowlands

Kenya partitions its basin territory into the Lake Victoria North (LVNCA) and Lake Victoria South (LVSCA) Catchment Areas. These two catchments are critical as they contribute approximately 59% of the surface water inflow to Lake Victoria (Winrock International, 2021).

- **Lake Victoria North (Nzoia–Yala):** Groundwater resources are dominated by the Mt. Elgon volcanic system and the Cherangany Hills, with renewable recharge estimated at 1,326 MCM/year but a tightly constrained safe yield of 116 MCM/year due to strong groundwater dependence of the Nzoia River system (BFI > 0.74) (JICA, 2013; Ministry of Water Kenya, 2020; Odwori, 2022). The Yala Swamp functions as a key regional groundwater discharge zone, but declining groundwater levels in the upper catchment (9.1–149.3 mm/year) threaten the hydraulic gradients sustaining swamp flows (Odwori, 2022).

- **Lake Victoria South (Sondu–Nyando–Mara):** The sub-catchment has higher renewable recharge (2,294 MCM/year) and a safe yield of 203 MCM/year (JICA, 2013), but groundwater development is constrained by hydrochemical risks. In the Kano Plains, high storage is offset by widespread salinity from evaporation and dissolution of lacustrine salts, while deeper regional aquifers—though volumetrically large—also exhibit high salinity, limiting their agricultural usability without desalination (Kanoti et al., 2020; Winrock International, 2021).

Uganda: The Wetland-Groundwater Nexus

In Uganda, the LVB falls under the jurisdiction of the Victoria Water Management Zone (VWMZ). The hydrogeology here is intricately linked with the country's extensive wetland systems, which act as recharge zones and hydraulic buffers (MWE, 2020).

- **Rwizi Catchment:** The Rwizi Catchment, which traverses Uganda's drought-prone Cattle Corridor, is underlain by a Regolith–Fracture aquifer system with poor and highly variable productivity due to discrete, poorly connected fractures (BGS, 2000; MWE, 2020). Although total renewable groundwater is estimated at 875 MCM/year against a modest demand of 26.35 MCM/year in 2020 (projected to 37.58 MCM/year by 2040), the low transmissivity of the aquifer means water cannot be pumped out fast enough to meet localized peak demands (e.g., for Mbarara city or large cattle herds). Declining water levels at Rwonyo and Rakai reflect both growing abstraction and reduced recharge linked to wetland drainage and broader catchment degradation, which has weakened the rainfall–recharge relationship (MWE, 2020; Owor et al., 2011).

- **Nakivale Sub-Catchment:** The Nakivale Sub-Catchment in Isingiro District, which supports major refugee settlements and intensive livestock grazing, is characterized by Ca–SO_4, Ca–HCO_3, and Na–Cl groundwater types controlled by feldspar weathering and sulfide oxidation (Barigye et al., 2024). Medium-to-high irrigation salinity hazards, elevated nitrate levels, and diagnostic Cl/Br ratios indicate risks to soils and evidence of wastewater and agricultural contamination despite clay-rich protective cover. While vulnerability assessments using the DRASTIC model classify most of the area as low vulnerability due to deep water tables (5–60 m) and thick argillaceous soils, localized high-vulnerability zones occur in sandy alluvial valleys where this protective layer is absent (Barigye et al., 2024).

Tanzania: The Granitic Shield and Mining Districts

Tanzania hosts the largest share of the Lake Victoria Basin (about 44%), extending across the semi-arid plains of Shinyanga, Mwanza, and Mara regions underlain predominantly by the Tanzania Craton. The hydrogeology of this part of the basin is therefore governed by fractured Precambrian basement rocks, which impose strong structural controls on groundwater occurrence, storage, and movement. Total renewable groundwater resources are estimated at about 1,327 MCM/year, representing roughly 10% of the total renewable water resources in the Tanzanian sector of the basin. Despite this relatively modest contribution, groundwater plays a strategically important role in sustaining livelihoods, settlements, and productive activities across northern Tanzania under highly variable climatic conditions.

Key features of the granitic shield aquifer systems include:

- **Aquifer Type and Yields:** dominated by basement complex aquifers characterized by low and highly variable borehole yields averaging 0.5–3 m^3/hour—adequate for rural hand pumps but insufficient for reliable piped town supply (Ministry of Water Tanzania, 2019).
- **Drilling Characteristics:** Average drilling depths are about 80 m with static water levels around 14 m, but dry boreholes are

common where fracture lineaments are not intercepted (IWMI, 2018).

- **Groundwater–Surface Water Interaction:** The Simiyu River is largely ephemeral with near-zero baseflow due to extremely high evapotranspiration losses, whereas the Mara River sustains baseflow from volcanic aquifers in the upper Mau catchment (Rwiza et al., 2012; Mariki et al., 2021).
- **Quality Pressures:** Mining activities in the lower Mara catchment pose growing risks to both surface and groundwater quality (Mariki et al., 2021).
- **Water Supply Dependency:** About 75% of all water points in the Tanzanian LVB are groundwater-based, with rural domestic supply accounting for roughly 50% of total abstraction, followed by livestock use in agro-pastoral zones such as Shinyanga (IWMI, 2018).

Rwanda and Burundi: The Headwaters

Rwanda and Burundi form the high-altitude hydrological source zone of the Kagera River, the largest tributary of Lake Victoria. Groundwater in these densely populated headwaters plays a critical role in sustaining wetlands, regulating baseflows, and supporting downstream water availability under highly variable climatic conditions.

- **Rwanda (Akanyaru–Nyabarongo System):** The Akanyaru catchment has a groundwater recharge and safe yield of about 531 MCM/year, with total storage estimated at 5,103 MCM and a mean residence time of approximately 10 years. The Lower Nyabarongo contributes an additional 545 MCM/year of renewable groundwater, but aquifer productivity is constrained by granitic and pegmatitic lithologies where deep, clay-rich weathering profiles limit borehole yields.
- **Burundi (Ruvubu Basin):** The Ruvubu basin, covering about 30% of Burundi, is characterized by steep, deforested slopes where removal of riparian vegetation and high erosion rates have reduced infiltration and accelerated surface runoff, producing extreme flood pulses and weakened dry-season baseflows (Heckmann et al., 2016). Recharge from the Burundian headwaters into the wider Kagera alluvial aquifer system is estimated at roughly 40 MCM/year (NBI, 2025).

Table 4-6. *Summary of Groundwater Resources by Catchment.*

Catchment	Country	Renewable Recharge (MCM/yr)	Safe Yield (MCM/yr)	Key Aquifer Type
LVNCA	Kenya	1,326	116	Volcanic/Basement
LVSCA	Kenya	2,294	203	Alluvial/Volcanic
Rwizi	Uganda	875	Not Defined	Regolith (Low T)
Akanyaru	Rwanda	531	~531	Granite/Pegmatite
Nyabarongo	Rwanda	545	~545	Schist/Quartzite
Tanzania LVB	Tanzania	1,327	~132	Granitic Basement

Source: *Synthesized from JICA (2013); MWE (2020).*

4.3.5 Groundwater–Surface Water Interaction

Across the Lake Victoria Basin (LVB), surface water and groundwater systems are tightly coupled through continuous hydraulic exchange. Rivers, wetlands, floodplains, and aquifers function as an integrated hydrological continuum in which groundwater sustains dry-season flows, moderates hydrological extremes, and regulates spatial and temporal water availability across the basin.

Baseflow Indices (BFI)

Baseflow Indices (BFI) are widely used to quantify the proportion of river discharge derived from groundwater by separating rapid surface runoff ("quick flow") from sustained subsurface contributions ("baseflow") in river hydrographs. Studies across the LVB reveal strong spatial contrasts in groundwater dependence among major rivers, reflecting differences in aquifer storage, lithology, and climatic controls:

- **Nzoia River (Kenya):** High BFI values (>0.74 in the lower reaches) indicate that groundwater sustains the river during the dry season, with BFI exceeding 0.94 during peak drought periods. This resilience reflects slow drainage from the Mt. Elgon volcanic aquifers (Odwori, 2022).
- **Simiyu River (Tanzania):** In contrast, the Simiyu River exhibits a near-zero BFI, indicating negligible groundwater contribution. Low-storage basement aquifers combined with extremely high evapotranspiration prevent effective recharge, rendering the river largely ephemeral (Rwiza et al., 2012).
- **Kagera River:** The Kagera maintains a substantial groundwater-supported baseflow, with mean annual discharge of about 3.15 km³—contributing roughly 30% of Lake Victoria's total riverine inflow. Extensive alluvial aquifers function as bank-storage reservoirs, absorbing floodwaters and sustaining dry-season flows (NBI, 2025).

Wetland Functions

Wetlands play a central role in regulating the hydrological exchange between surface water and groundwater systems across the basin by functioning as natural hydraulic buffers. In the Lake Victoria Basin, wetlands enhance recharge of shallow alluvial aquifers during floods, store water within organic and sediment matrices, and sustain river baseflows through gradual groundwater discharge during dry periods. The Kagera floodplain wetlands are particularly important for sediment trapping and flow attenuation; their degradation would simultaneously reduce groundwater recharge and accelerate sediment delivery to Lake Victoria (NBI, 2025). In the Yala Swamp, groundwater–surface water interaction is distinctly bidirectional: high river stages drive infiltration into the aquifer, while falling levels reverse the gradient and induce sustained groundwater discharge into the wetland, maintaining perennial flow and ecological functions (Mutua et al., 2020).

4.3.6 Groundwater Utilization and Sectoral Demand

Groundwater is a strategic and increasingly stressed water source across the Lake Victoria Basin, underpinning domestic supply, agricultural production, extractive industries, and emerging aquaculture systems. While overall abstraction remains spatially diffuse and unevenly regulated, sectoral pressures are intensifying under rapid population growth, urban expansion, and economic transformation.

- **Domestic Supply:** Groundwater is the primary source of water for rural communities, supporting an estimated 25–30 million people through hand pumps (Figure 4-15), shallow wells, and protected springs. In secondary towns and cities such as Mbarara and Kisumu, private boreholes are increasingly used to supplement intermittent municipal supplies. In mining zones such as Geita, mining companies now provide piped water to surrounding communities to compensate for the impacts of large-scale dewatering and contamination risks, reflecting an evolving social license to operate (Emel et al., 2014; Barrick Gold Corporation, 2024).



Figure 4-15. *Children fetching water from a rural borehole in Ngozi Provide, Burundi.*

- **Agriculture and Irrigation:** Groundwater irrigation currently accounts for a very small fraction of total water use in most sub-basins (generally <2%), but represents the basin's largest latent growth frontier for food production and climate adaptation (JICA, 2013) (Textbox 4-1).. High-capacity abstraction is physically viable only in high-yield systems such as the Kagera alluvial aquifer ($T \approx 129\ m^2/day$), while the extensive basement complex zones are restricted to low-intensity technologies—such as solar-powered drip irrigation and smallholder gardening—due to low transmissivity and borehole yields (Ozan et al., 2018; Ministry of Water Tanzania, 2019).
- **Mining and Industry:** Mining represents the most intense and localized form of groundwater use in the basin. At the North Mara Gold Mine, total process water demand is approximately 9,000 m^3/day, of which about 5,000 m^3/day is internally recycled, leaving a residual demand of roughly 4,000 m^3/day sourced from external surface and reclaimed tailings water (Shelp & Sibilski, 2009). At the Geita Gold Mine, underground dewatering requirements have risen sharply from around 10 m^3/day in 2002 to over 1,000 m^3/day in recent years, generating extensive cones of depression that can dry up shallow community wells and alter local groundwater flow systems (Shelp & Sibilski, 2009).
- **Aquaculture:** Cage aquaculture in Lake Victoria is expanding rapidly, producing about 10,000 tonnes per year in Kenya alone, while land-based aquaculture using groundwater remains limited but is gaining interest as lake water quality declines due to eutrophication (Kenya Marine and Fisheries Research Institute, 2021). This transition towards pond-based systems could introduce new abstraction and pollution pressures on shallow aquifers, particularly in the wetland-fringed zones surrounding the lake.

Textbox 4-1: Groundwater-Based Irrigation in the Lake Victoria Basin

The Lake Victoria Basin countries possess significant untapped groundwater potential for irrigation, though current utilization remains minimal and unevenly distributed. The region's aquifer systems—ranging from high-yield sedimentary formations along lake shorelines to low-yield weathered basement rocks in upland areas—offer varying irrigation capabilities depending on location and hydrogeological conditions.

In **Kenya,** the National Water Master Plan 2030 identifies 623,675 ha of national irrigation potential, with more targeted assessments in the Lake Victoria South Catchment Area indicating scope for approximately 6,867 ha of new groundwater-fed irrigation by 2030, largely driven by smallholder farmers and private investors adopting high-efficiency technologies such as drip irrigation. About 40% of the Lake Victoria South population already relies on groundwater from boreholes and springs, providing a strong foundation for incremental irrigation expansion.

Tanzania, which contains 64% of the Kagera Basin, aims to expand irrigated land from 0.2 million to 1.0 million ha by 2035. Groundwater currently plays a supplementary rather than primary role—despite being widely described as the country's "sleeping giant." Most large-scale schemes in the Mara and Bugwema areas remain predominantly surface-water-based.

Uganda shows the lowest groundwater irrigation utilization rate, at just 0.5% of estimated potential, even though renewable groundwater resources are estimated at 29,000 million m^3/year. Progress is emerging through decentralized solutions: by 2024, the Micro-scale Irrigation Programme had installed 4,733 solar-powered systems covering 3,360 ha, with a long-term target of reaching 83,000 farmers.

Rwanda, which overlies 13% of the transboundary Kagera Aquifer system, is increasingly using borehole-supported dry-season agriculture in the Akagera catchment as a climate-resilience strategy to stabilize food production during prolonged dry spells.

Burundi, facing extreme demographic pressure with 47% of the Kagera Basin population, has an estimated 122,701 ha of irrigation potential, of which only 33% is currently utilized, even though groundwater supplies about 90% of national water use.

Across the basin, the gradual transition from rain-fed to groundwater-based irrigation is being enabled by solar-powered pumping technologies, but remains constrained by high drilling costs (USD 7,500–12,000 per borehole), limited aquifer characterization, and weak integration of groundwater into national irrigation planning frameworks.

4.3.7 Transboundary Aquifers: Identification and Significance

Groundwater governance in the Lake Victoria Basin is complicated by the misalignment between political borders and hydrogeological systems. Several major transboundary aquifers (TBAs) facilitate cross-border groundwater flow between Partner States but remain far less regulated than shared surface waters. Regional diagnostics led by IGAD and the Nile Basin Initiative (NBI) identify three priority TBAs requiring cooperative management: Mount Elgon, Sio–Malaba–Malakisi (SMM), and Kagera (IGAD, 2022; NBI, 2025a; NBI, 2025b).

Priority Transboundary Aquifer Systems

- **Mount Elgon Aquifer (Kenya–Uganda):** The Mount Elgon TBA is a high-altitude volcanic system that functions as a regional recharge "water tower," sustaining baseflows to the Sio, Malaba, and Nzoia rivers and supplying domestic water to dense transboundary populations. Radial groundwater flow across the border creates strong hydraulic interdependence, yet no dedicated legal or institutional framework currently governs its shared management (IGAD, 2022; NBI, 2025a).
- **Sio–Malaba–Malakisi Aquifer (Kenya–Uganda):** The SMM system consists of shallow alluvial and weathered basement aquifers hydraulically linked to the transboundary river network and supporting over four million people. Its unconfined nature makes it highly vulnerable to pollution from sanitation, agriculture, and localized mining. Although joint planning efforts exist, cooperation remains largely surface-water focused, with limited groundwater-specific agreements (IGAD, 2019; Mwanake et al., 2025).
- **Kagera Aquifer (Burundi–Rwanda–Tanzania–Uganda):** The Kagera aquifer is the largest and most strategic TBA in the basin, underlying extensive alluvial plains and wetlands across four countries. With estimated storage of about 50 BCM, it provides a major drought buffer and plays a central role in sustaining Kagera River baseflows. It is hydraulically connected to the river system but largely isolated from Lake Victoria by basement rocks, limiting direct lake–aquifer exchange (BGS, 2023; NBI, 2025b).

Management Implications

While transboundary aquifer assessments have advanced from mapping to diagnostic analysis, shared groundwater governance remains a critical gap. Existing regional frameworks focus overwhelmingly on surface water, despite the high vulnerability of shallow systems such as the SMM and Kagera aquifers to cross-border pollution. Effective management requires harmonized land-use controls, aligned water-quality standards, and formal institutional mechanisms dedicated to transboundary groundwater cooperation (NBI, 2023).

4.3.8 Groundwater Monitoring and Data Availability

Groundwater monitoring remains the weakest component of water resources management in the Lake Victoria Basin. Unlike surface water, which benefits from sustained regional investments, groundwater observation is fragmented, project-based, and spatially sparse, with no real-time basin-wide network in operation (UKCEH, 2023).

At the national level, Kenya, Uganda, and Tanzania operate limited monitoring borehole networks, but long-term continuity and rural basement coverage remain inadequate. Tanzania's Lake Victoria Basin Water Board has formally prioritized the establishment of monitoring stations, while Kenya's NWMP 2030 identifies network expansion as a strategic gap (Lake Victoria Basin Water Board, 2019). At the transboundary scale, the Nile Basin Initiative has initiated targeted monitoring in shared aquifers such as the Sio–Malaba–Malakisi system, but coverage remains partial and uneven (IGAD, 2019).

Data scarcity is acute: most groundwater information is derived from short-term studies rather than continuous records, leaving major gaps in long-term water-level trends, storage behavior, abstraction rates, and ambient water quality baselines. The LVBC Water Information System (WIS) represents a major institutional advance toward harmonized basin-wide data management, but it is not yet fully operationalized for groundwater (LVBC, 2024).

The absence of robust groundwater monitoring constitutes a "silent risk" for the basin. Without reliable abstraction and trend data, sustainable yield estimates remain largely theoretical. Closing this gap through operational regional monitoring is a prerequisite for effective groundwater governance and long-term water security.

4.4 Threats to Water Resources of the Lake Victoria Basin

4.4.1 Overview

The Lake Victoria Basin underpins agriculture, fisheries, hydropower, industry, and domestic water supply for the over 45 million residents in the basin, but faces escalating and interlinked pressures on its water resources. Rapid population growth, urbanisation, climate change, and ecosystem degradation are progressively eroding the basin's capacity to regulate flows, maintain water quality, and buffer climatic extremes. These pressures are mutually reinforcing: land and ecosystem degradation directly alters hydrological regimes and water quality, while climate change acts as a powerful threat multiplier. Without coordinated action, the basin risks entering a self-reinforcing cycle of environmental decline and socio-economic stress.

4.4.2 Key Threats to Water Resources

Key threats to the basin's water resources are the following:

- **Climate Change and Hydrological Variability:** Rising temperatures and shifting rainfall patterns have intensified floods, droughts, and lake-level fluctuations. Rainfall is increasingly concentrated in short, intense events separated by longer dry spells, while warming enhances evapotranspiration, thermal stratification, and hypoxia in the lake. These changes threaten water supply reliability, ecosystem health, and hydropower generation, which remains central to regional energy systems.
- **Land-use Change and Deforestation:** Expansion of cropland and urban areas has occurred largely at the expense of forests, wetlands, and rangelands. Loss and fragmentation of key montane forests and headwater catchments reduce infiltration and groundwater recharge while increasing runoff, erosion, and flood peaks. Hydrological systems have become more variable, with higher floods and reduced dry-season flows, increasing vulnerability even in average rainfall years.
- **Unsustainable Resource Use and Rising Demand:** Agriculture employs most basin residents but is characterised by land degradation, expansion into fragile areas, and inefficient input use. Overfishing, wetland biomass harvesting, and fuelwood extraction further degrade ecosystems that sustain water resources. Rising populations, climate-induced migration, and urban growth are intensifying demand for water, sanitation, and land in already stressed areas.
- **Industrial, Mining, and Emerging Contaminants:** Industrial effluents, mining activities, and poorly managed waste introduce heavy metals and toxic substances into surface and groundwater. Emerging pollutants—plastics, microplastics, pharmaceuticals, pesticides, and persistent organic pollutants—are increasingly detected, bioaccumulate in food webs, and present poorly understood long-term health risks.
- **Wetland Degradation:** Wetlands—critical for flood buffering, water purification, and dry-season flow regulation—have declined by roughly one-third since the 1980s. Agricultural encroachment, drainage, and urban expansion have reduced their capacity to trap sediments and nutrients, regulate flows, and support fisheries and biodiversity, while peatland loss contributes to greenhouse-gas emissions.
- **Soil Erosion and Sedimentation:** Highly erodible soils, vegetation clearance, and intense rainfall have driven widespread erosion. A small number of rivers deliver the majority of sediment to the lake, degrading riverine and nearshore habitats, increasing turbidity, transporting pollutants, and raising water-treatment costs for urban supplies.

- • Sanitation and Wastewater Pollution: Rapid and unplanned urbanisation has outpaced sanitation infrastructure. Millions lack access to basic sanitation, and major urban tributaries discharge untreated domestic and industrial wastewater into the lake. Microbial contamination and cyanotoxins pose serious public-health risks, particularly for lakeshore and fishing communities.
- **Nutrient Enrichment and Eutrophication**: Excessive nutrient inputs from agriculture and untreated wastewater have caused persistent eutrophication, harmful algal blooms, and widespread oxygen depletion. Internal nutrient recycling from anoxic bottom waters sustains a self-reinforcing degradation cycle, with nearshore zones and semi-enclosed gulfs remaining chronic pollution hotspots. Biodiversity loss has been severe, with most endemic fish species now threatened.
- **Groundwater Degradation:** Groundwater, the main drinking-water source for rural communities, faces growing contamination from sanitation, agriculture, and natural geochemical hazards. Nitrate, microbial, fluoride, iron, and arsenic contamination are widespread. Polluted groundwater feeds back into rivers and wetlands, compounding surface-water degradation, while climate variability threatens recharge reliability.
- **Ecosystem Imbalance and Invasive Species:** Invasive species, particularly water hyacinth, proliferate in nutrient-rich waters, obstructing navigation, water intakes, and hydropower infrastructure while increasing evapotranspiration losses. Altered food webs and reduced biodiversity from fish species introductions weaken ecosystem resilience and water-quality regulation.
- **Governance and Monitoring Gaps:** Despite an established regional legal framework, enforcement remains uneven. Monitoring networks are fragmented, data are poorly harmonised, and institutional capacity and financing are insufficient. Past gains remain vulnerable without sustained political commitment and long-term investment

4.4.3 Conclusion and Outlook

Water insecurity in the Lake Victoria Basin is increasingly driven by the interaction between ecosystem degradation and climate change, which together undermine hydrological stability, water quality, and ecosystem resilience. Deforestation, wetland loss, pollution, and unsustainable resource use amplify floods, droughts, and evapotranspiration, reinforcing a poverty–environment trap that threatens livelihoods, public health, and regional stability.

Reversing these trends requires integrated and transformative action, including climate-resilient sanitation and wastewater treatment, stricter control of industrial and mining pollution, restoration of forests and wetlands, sustainable groundwater management, and the adoption of climate-smart agriculture. Equally important are strengthened regional coordination, harmonised monitoring systems, and evidence-based basin planning. With sustained political commitment and investment, the basin can still secure its water resources and safeguard its role as the ecological and economic backbone of East Africa.

4.5 Water Resources Monitoring

Water resources monitoring and data management form the backbone of evidence-based water governance in the Lake Victoria Basin, underpinning flood early warning, hydropower regulation, water resources development, pollution control, and climate risk management. **Section 4.4** examines the structure and performance of hydrometric, meteorological, groundwater, and water quality monitoring networks across the basin, and evaluates the transition toward automation, telemetry, and regional interoperability. It further assesses data integration systems, operational sustainability, and the persistent institutional and financing gaps that constrain effective basin-wide monitoring.

4.5.1 Overview

Effective management of the Lake Victoria Basin (LVB) depends on sustained access to reliable hydrological, meteorological, and groundwater data, which underpin water allocation, flood risk management, hydropower operations, and pollution control. Historically, basin monitoring evolved through fragmented national systems with uneven capacity and limited data integration.

In the lead-up to the 2025 State of the Basin Report, however, large-scale modernization— driven by national reforms and development partner investment—has shifted the network toward automation, telemetry, and regional interoperability.

Hydrometric and Hydrological Monitoring

Hydrological monitoring across the LVB remains nationally managed, with coverage and functionality varying widely (Figure 4-16 and Figure 4-17). The basin exhibits a hybrid architecture: pockets of modern telemetry embedded within a broader legacy network dominated by manual equipment.

- Kenya operates one of the most advanced networks under the Water Resources Authority (WRA), with a nationally rationalized target of 223 surface-water stations. By 2023, 118 stations had been upgraded to real-time telemetry using GPRS and satellite systems, supporting high-frequency flood monitoring on volatile rivers such as the Nzoia and Yala. The network exhibits high effective density, reflecting intensive flood risk monitoring in these key catchments. Acoustic Doppler Current Profilers (ADCPs) are now standard for rating-curve calibration, significantly improving discharge accuracy and operator safety. However, long-term sustainability remains constrained by dependence on project-funded operations, particularly for GSM airtime, sensor maintenance, and security of field equipment (WRA, 2023; WRA, 2024).
- Uganda, through the Victoria Water Management Zone under the Ministry of Water and Environment, has rebuilt much of its network following collapse during the 1970s–1980s. As of 2024, 91 surface-water stations are operational and centrally coordinated through the Water and Environment Information System (WEIS), with at least 32 transmitting data in real time using automatic water-level recorders (pressure transducers, radar, and ultrasonic sensors). The network shows substantial recovery from historical collapse, although gaps remain in wetland-dominated zones. Flood damage to stations on the Katonga and Kafu rivers during recent extreme events highlights the growing need for climate-resilient monitoring infrastructure designed for higher flood recurrence intervals, especially given the network's role in regulating hydropower releases at Jinja (MoFPED, 2024; MWE, 2024).
- Tanzania manages the largest station inventory nationwide (over 1,100), but only about two-thirds are fully functional. Within

the LVB, despite having the largest lake frontage and highest total station count, effective density per unit area remains lower than Kenya or Rwanda, with monitoring concentrated around Mwanza and the Mara River. Targeted densification has added new stations on critical tributaries, including the transboundary Mara River. The continued reliance on manual staff gauges offers low-cost resilience but limits real-time applications, increases data latency, and suffers from data gaps during floods and at night (Ministry of Water, 2024).

- Rwanda, occupying the steep upper Akagera catchments, operates the densest and most technologically advanced network relative to its size. Real-time radar and satellite-linked stations—many supported through Nile Basin Initiative (NBI) investments—provide high-resolution flood and sediment monitoring critical for disaster risk reduction and downstream flow forecasting. Rwanda increasingly favors non-contact radar sensors to reduce siltation damage in its volcanic catchments (RWB, 2024; MoE Rwanda, 2023).
- Burundi remains the most data-constrained and severely under-instrumented part of the basin, particularly in the upper Ruvubu and Akanyaru sub-catchments. Severe institutional and financial limitations within IGEBU have created a major blind spot in Kagera inflow estimation, undermining confidence in basin-wide hydrological accounting. While recent rehabilitation projects are underway, the system still represents a structural gap in regional monitoring (World Bank, 2018; World Bank, 2020).

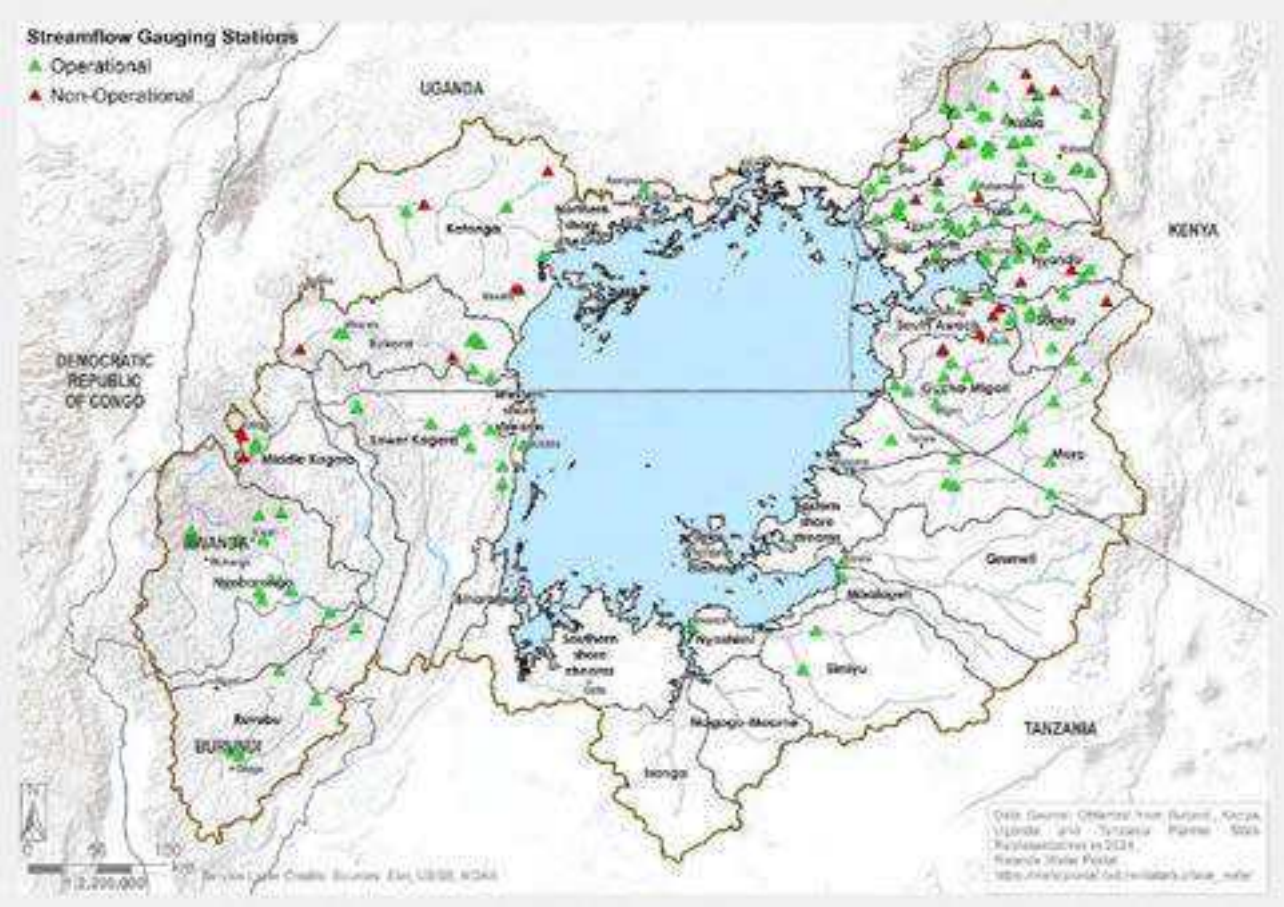


Figure 4-16. *Streamflow gauging stations in the Lake Victoria Basin*

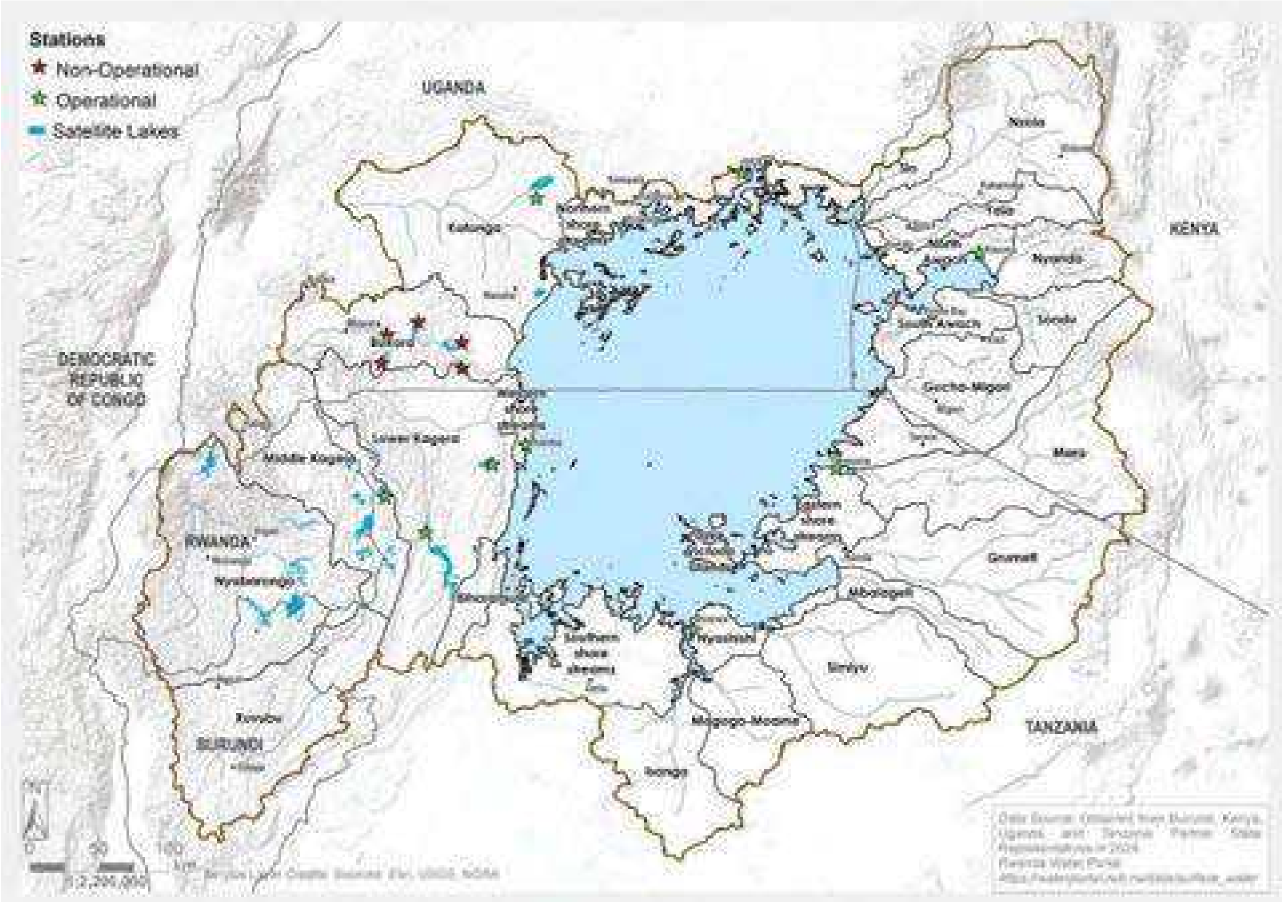


Figure 4-17. *Lake level monitoring stations in the Victoria Basin*

Meteorological and Climate Monitoring

Meteorological monitoring is central to Lake Victoria Basin (LVB) water balancing, as more than 80% of lake inflows derive directly from rainfall and a comparable proportion is lost through evaporation. Accurate climate observations are therefore fundamental to flood forecasting, drought analysis, hydropower optimization, and climate risk management.



Figure 4-18. *Kanzenze Hydrological Monitoring Station on the Akagera River, Rwanda. This is one of six modern hydrological stations installed by the Nile Basin Initiative in Rwanda in 2023. (Credit: Ministry of Environment, Rwanda).*

Across the basin, National Meteorological and Hydrological Services are rapidly transitioning from manual gauges toward Automatic Weather Stations (AWS) and real-time data transmission (Figure 4-18). Kenya has modernized 55 climatic stations under its national climate network, enabling sub-daily rainfall monitoring critical for flood-prone urban areas and agricultural planning (WRA, 2023). Rwanda operates one of the region's most advanced climate networks, with over 300 observation points and 39 synoptic stations aligned to World Meteorological Organization (WMO) Global Basic Observing Network (GBON) standards, although gaps persist in upper-air observations needed to improve numerical weather prediction (Rwanda Meteorology Agency, 2023). Tanzania maintains a large national network of over 340 stations, with strong coverage along the southern lake shoreline (Ministry of Water, 2024).

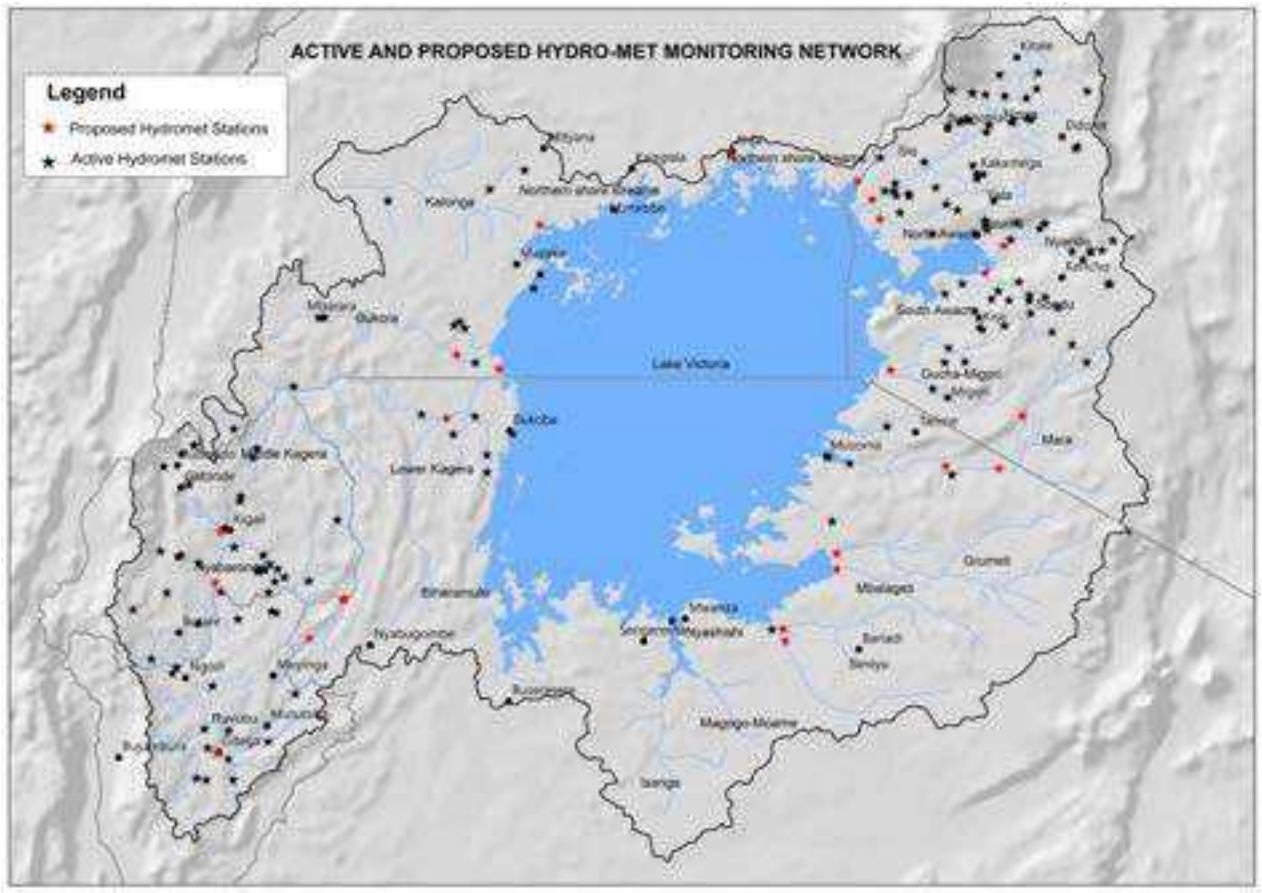


Figure 4-19. *Hydrometeorological monitoring stations in the Lake Victoria Basin.*

At the regional scale, the WMO's HydroSOS initiative is being piloted in the LVB to integrate climate and hydrological data into standardized, decision-ready products on drought, floods, and water availability. This marks a critical transition from fragmented observation systems toward a basin-scale climate services architecture (WMO, 2023).

Groundwater Monitoring

Despite its strategic importance to water security and climate resilience, groundwater monitoring remains the weakest component of the Lake Victoria Basin (LVB) water information system. While surface-water networks have benefited from sustained regional investment, groundwater observation is still largely fragmented, project-driven, and spatially sparse. As reliance on aquifers for rural supply and irrigation increases, the absence of continuous abstraction and water-level data creates a high risk of invisible over-exploitation without early warning.

At the national level, capacity varies significantly:

- Kenya leads regional efforts through targeted hydrogeological investments, including the Horn of Africa Groundwater for Resilience Project, and currently monitors about 36 dedicated groundwater observation wells in the Lake Victoria North Basin. However, coverage remains thin in rural basement aquifers, and expansion targets are frequently constrained by drilling and recurrent cost limitations (WRA, 2024).
- Uganda operates one of the most mature groundwater monitoring systems in the basin, with 81 active observation stations and some continuous records extending back to the late 1990s. However, only a small subset of these stations currently

transmit data in near-real time, limiting their operational value for drought early warning (IGRAC, 2024; Winrock, 2021).

- Tanzania reports 95 monitoring stations nationally, with basin coverage concentrated around Mwanza and other urban centers where abstraction pressure is rising (Ministry of Water, 2024).
- Rwanda has made recent strides in formalizing its network under the Rwanda Water Resources Board (RWB), which now operates approximately 11 automatic groundwater monitoring stations and 8 manual piezometers. These are strategically focused on the drought-prone Eastern Province and high-yield volcanic aquifers in the northwest. Despite this progress, the network remains insufficient to capture complex interactions between surface water and groundwater in the fractured basement rocks that dominate the Kagera sub-basin, and data integration into regional models remains limited (RWB, 2024; FutureWater, 2023).
- Burundi possesses the most nascent monitoring infrastructure in the basin, with groundwater oversight managed by IGEBU (Institut Géographique du Burundi). Monitoring is almost entirely project-dependent, with a small cluster of observation wells established primarily around the Gitega (Nyanzare) and Kirundo wellfields through cooperation with German partners (BGR). Outside these specific project areas, there is no systematic national groundwater observation network, leaving the country's significant crystalline aquifers largely unmonitored against climate variability (IGEBU/BGR, 2022).

The current monitoring network is shown in **Figure 4-20** below.

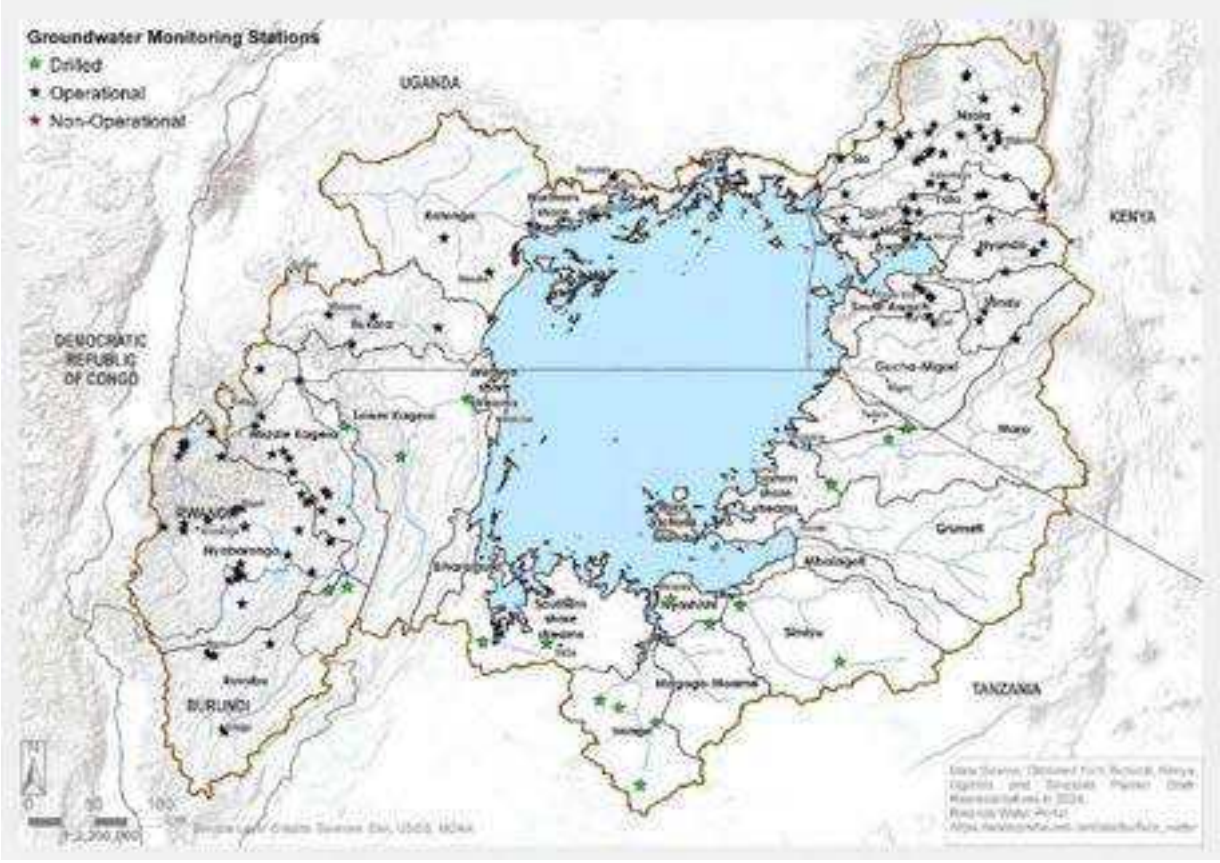


Figure 4-20. *Groundwater monitoring stations in the Lake Victoria Basin*

A major systemic weakness is the absence of harmonized monitoring of transboundary aquifers, particularly within the Kagera system shared by Tanzania, Uganda, and Rwanda. While the Nile Basin groundwater database aggregates available national datasets, it remains dependent on episodic studies rather than systematic real-time monitoring (NBI, 2025).

Overall, the shift from groundwater estimation to active groundwater management will require urgent operationalization of permanent, telemetered regional monitoring networks as envisaged in basin IWRM strategies. Without this transition, the basin risks the unmanaged depletion of its most resilient strategic water reserve.

Lake Water Quality Monitoring

Lake water quality monitoring is essential for understanding how Lake Victoria responds to land-use change, riverine pollutant inflows, and internal limnological processes that regulate algal productivity, sediment dynamics, and dissolved oxygen. As a large, shallow, wind-mixed tropical lake, it is highly sensitive to nutrient enrichment, making sustained in-lake monitoring critical for eutrophication control, fisheries management, and ecosystem health.

The most comprehensive lake-wide monitoring system was established under LVEMP I, which created 57 permanent sampling stations (26 littoral and 31 pelagic) (Figure 4-21). These stations supported vertically resolved water column profiling and integrated monitoring of nutrients, sediments, plankton communities, benthic conditions, and dissolved oxygen, alongside river hydrology, currents, and meteorology. This system provided the scientific foundation for understanding the linkage between catchment nutrient loading, algal blooms, and deep-water hypoxia.

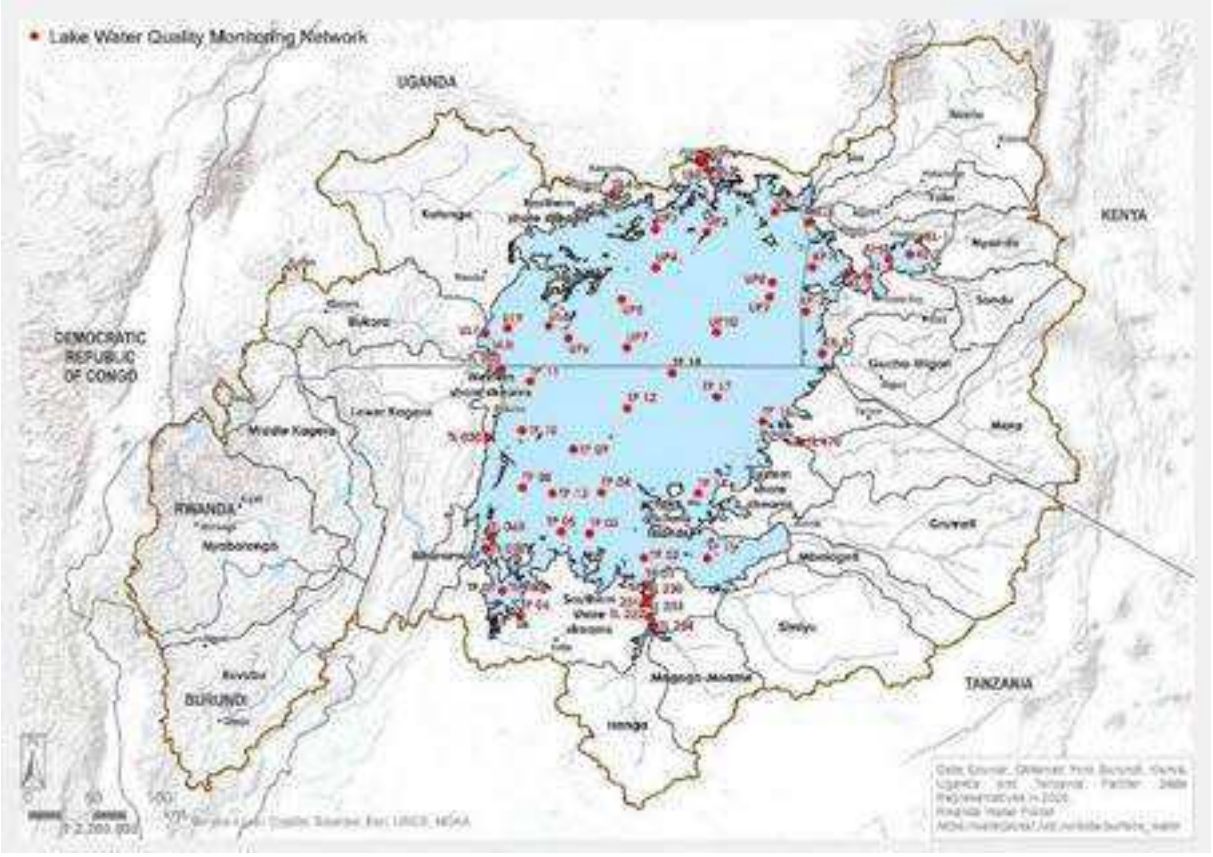


Figure 4-21. *Lake wide water quality monitoring stations established under the LVEMP I Project.*



Figure 4-22. *Staff of the Water Quality Management Department in Uganda carrying out limnological measurements on Lake Victoria.*

After LVEMP, routine basin-wide monitoring weakened, and lake sampling became largely ad hoc and nationally driven (Figure 4-22), with reduced spatial coverage and temporal consistency. This constrained long-term tracking of eutrophication trends, hypoxia development, and climate-driven mixing variability.

Lake-wide monitoring has now been formally revived under the coordination of the Lake Victoria Basin Commission (LVBC). Central to this recovery is the Research Vessel (RV) Jumuiya, the basin's only offshore limnological platform. After more than a decade of inactivity (2012–2023), the vessel was rehabilitated and recommissioned for lake research.

The vessel supported the 2025 basin-wide joint lake monitoring campaign, involving Kenya, Tanzania, and Uganda—the first fully coordinated lake-wide survey in over two decades. The mission covered 44 of the 98 harmonized LVEMP-I stations and produced a single, unified lake water quality dataset for the State of the Basin Report 2025 (GIZ, 2025), marking a decisive return to standardized, cooperative lake science.

Water Quality Monitoring in the Terrestrial Catchment

Water quality monitoring across the terrestrial catchment of the Lake Victoria Basin (LVB) is essential for tracking pollutant loads entering the lake, identifying pollution hotspots, and supporting mass-balance assessments of nutrients and sediments. Monitoring capacity, however, remains highly uneven across Partner States, reflecting wide disparities in institutional strength, laboratory infrastructure, and sustained operational financing.

- Kenya operates the most extensive river water quality monitoring network in the basin (Figure 4-23), with about 136 routine monitoring sites across major tributaries such as the Nzoia, Nyando, Yala, Sondu-Miriu, and Kuja. Monitoring covers standard physico-chemical and nutrient parameters, supported by a relatively strong laboratory base in Kisumu. However, laboratories remain unaccredited, advanced residue analyses are largely outsourced, and irregular sampling and data gaps persist due to budget and maintenance constraints.
- Tanzania, which drains the largest share of the basin, maintains a formally structured national network established under LVEMP, covering key rivers including the Kagera, Mara, and Simiyu. The basin is supported by accredited zonal and regional laboratories in Mwanza, Musoma, Bukoba, and Shinyanga, making Tanzania the strongest in laboratory quality assurance. Nevertheless, sampling frequency is inconsistent, data sharing remains fragmented, and maintenance of advanced instruments is costly.
- Uganda possesses a comprehensive water quality monitoring and laboratory infrastructure in the Lake Victoria basin, with national monitoring stations covering

rivers such as Katonga, Rwizi/Bukora, Kagera at Kasensero; small lakes like Wamala, Kijjanibarora, and Nabugabo; and pollution hotspots in Inner Murchison Bay and cities like Kampala, Entebbe, Jinja, Masaka and Mbarara (Figure 4-23). A three-tier laboratory system anchored by the National Water Quality Reference Laboratory provides advanced analytical capacity. However, operational funding constraints limit routine monitoring, with less than full network coverage achieved in practice.

- Rwanda operates a developing national monitoring network across the Akagera and associated lakes, supported mainly through external laboratory testing services. Routine monitoring focuses on basic nutrients and physico-chemical parameters, while agrochemical and heavy metal analysis remains largely unavailable.
- Burundi remains severely under-instrumented, with no permanent river water quality monitoring network and very limited laboratory capability. Water quality data are derived mainly from isolated research projects, with major gaps for industrial pollutants, pesticides, and heavy metals.

Across the basin, routine river monitoring generally covers pH, electrical conductivity, turbidity, dissolved oxygen, BOD, COD, nutrients (nitrogen and phosphorus), total suspended solids, and major ions. However, monitoring of pesticide residues, heavy metals, hydrocarbons, and emerging micropollutants is weak or absent in most countries, except at a few specialized laboratories in Uganda, Tanzania, and Kenya.

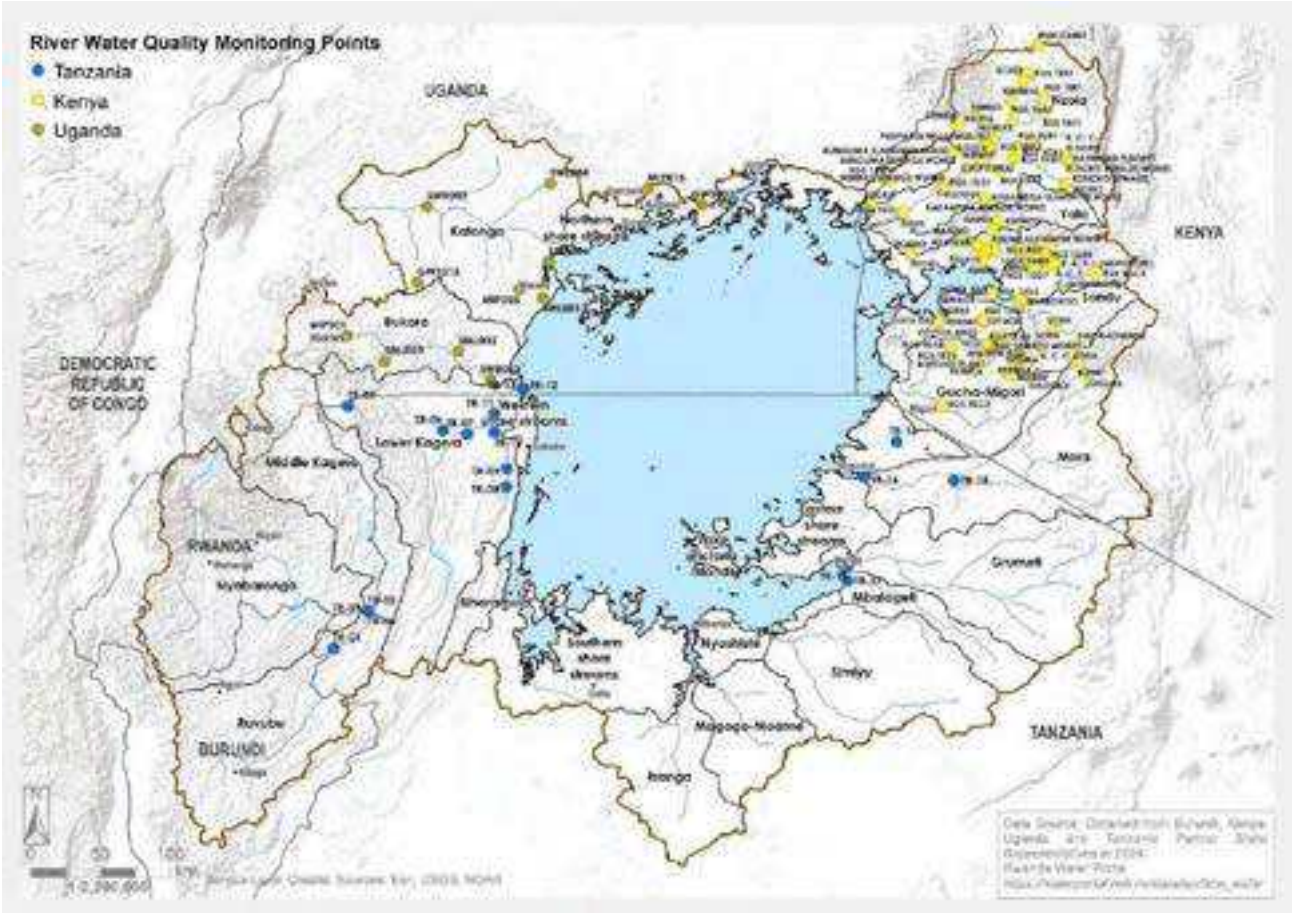


Figure 4-23. *Network of water quality monitoring stations in the terrestrial catchment of Lake Victoria.*

4.5.2 Cross-Cutting Challenges and future options

Across all monitoring domains in the Lake Victoria Basin, a set of systemic challenges continues to constrain the reliability, sustainability, and regional integration of monitoring systems:

- **Financing and Sustainability:** A persistent mismatch exists between donor-funded capital investment and weak recurrent financing for maintenance, calibration, data transmission, security, and consumables. As a result, many stations deteriorate soon after project closure, creating a recurring cycle of installation, short-term functionality, and long-term decline. In the water quality sector, this is compounded by frequent equipment breakdowns, slow replacement cycles, and vandalism of field installations.
- **Climate Vulnerability of Infrastructure:** Monitoring assets designed for historical hydrological conditions are increasingly damaged by floods, sedimentation, and debris. Minimum-cost civil works are no longer adequate under rising flood magnitudes, necessitating a shift toward climate-resilient designs with reinforced structures, non-contact sensors, and redundant power and communication systems.
- **Weak Data Integration and Interoperability:** Incompatible data formats, limited real-time cross-border data sharing, and the absence of a unified basin-wide platform continue to constrain transboundary early warning, regional modeling, and coordinated decision-making.
- **Uneven Spatial Coverage:** Monitoring density remains highly skewed toward accessible, high-risk zones, with persistent blind spots in remote headwaters, wetlands, and upstream transboundary catchments—most critically in Burundi's Ruvubu and Akanyaru sub-basins. Groundwater monitoring is systematically weak across all Partner States, and transboundary aquifer surveillance is virtually absent.
- Institutional and Human Capacity Gaps: Persistent constraints include staff turnover, limited specialized training, weak quality assurance systems, and low analytical capacity for emerging pollutants. These challenges are most acute in Burundi but affect all Partner States to varying degrees.

Path Forward

The basin has moved decisively toward real-time monitoring, but its full value will only be realized through a shift from project-based expansion to sustained operational systems, from fragmented national networks to integrated basin-wide platforms, and from reactive maintenance to proactive climate-resilient design. Addressing these priorities is essential for monitoring systems to reliably support integrated water resources management in the Lake Victoria Basin.

4.6 Water Resources Data Management

Water resources data management is central to credible basin planning and management. While Section 4.4 focuses on the physical monitoring networks themselves, Section 4.5 addresses what happens to the data they generate—its availability, continuity, quality, integration, and use in decision-making. It examines hydrometric record gaps, priority data deficiencies, national and regional systems for data management and standardization, decision-support platforms, and the legal and technical frameworks governing transboundary data exchange.

4.6.1 Data Availability: Historical Records and Current Data Collection

Hydrometric data availability in the Lake Victoria Basin reflects a legacy of strong historical observation followed by prolonged institutional decline and only partial recovery. While recent reforms and digital systems signal improvement, Figure 4-24 confirms that large structural gaps persist across the basin, and operational coverage remains far below pre-1970s levels. The contemporary network is limited to a small number of intermittently functioning stations, with widespread discontinuities in discharge records—reflecting chronic under-resourcing of monitoring operations.

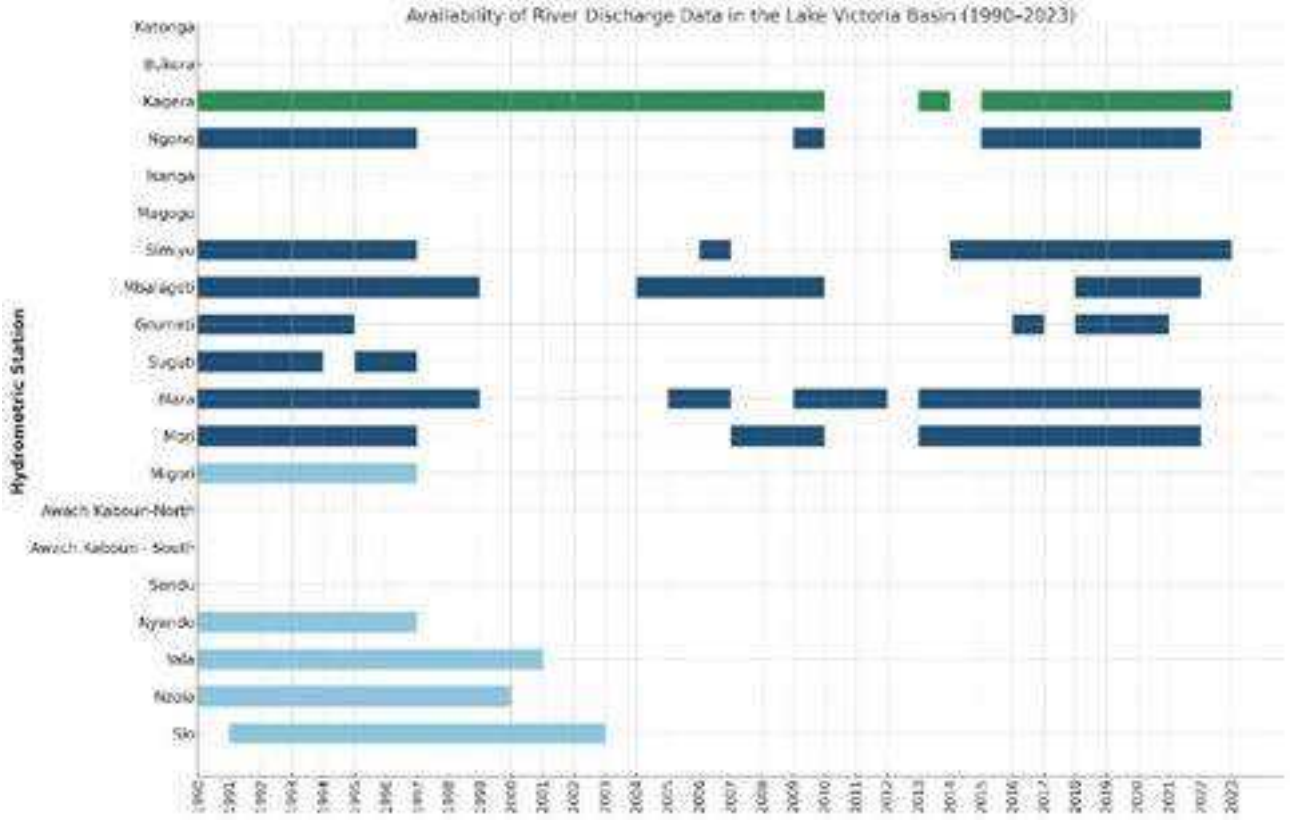


Figure 4-24. *Availability of river discharge data in the Lake Victoria Basin (1990-2023).*

The basin's long-term foundation remains the Hydromet Survey (1967–1992), which established the core hydro-climatic baseline (NBI, 2021). This capacity deteriorated sharply from the late 1980s due to political instability, institutional restructuring, and under-investment, leading to extensive loss of stations and fragmented time series, particularly in Uganda and Burundi (Winrock, 2021). Although historical data rescue is underway—notably the digitization of groundwater records for over 30 Ugandan stations since 1998 (IGRAC, 2024)—these efforts recover only a limited share of what was lost.

Current monitoring increasingly relies on telemetry, digital platforms, and regional cooperation. Kenya's telemetric network and Uganda's WEIS now support near–real-time reporting at selected sites (WRA, 2023; MWE, 2024), while the 2025 basin-wide lake water-quality survey marked a major step toward harmonized regional assessment (LVBC, 2025). At the same time, Earth Observation products integrated through the LVB-WIS are filling critical spatial gaps for land use change, floods, and algal blooms, but cannot substitute for in-situ discharge measurement for operational water management.

Overall, the basin is transitioning toward a more digitally enabled and coordinated monitoring environment, but this recovery remains fragile and uneven. Sustained progress will depend on shifting from project-based rehabilitation to stable domestic financing for network operation and maintenance, systematic historical data rescue, and the institutionalization of joint regional monitoring. Until these conditions are secured, improvements in data availability should be viewed as important but tentative gains, rather than a full resolution of the basin's long-standing hydrometric deficit.

4.6.2 Critical Data Gaps and Priority Areas for Improvement

Despite recent modernization, several structural data gaps continue to constrain reliable basin planning and effective transboundary water management in the Lake Victoria Basin.

Spatial and Temporal Gaps

- **Upper Catchment Blind Spots:** The densely populated headwaters in Burundi and Rwanda remain under-monitored despite their hydrological complexity. Sparse monitoring in Burundi in particular creates major uncertainty in Kagera River inflow estimates before the Rwanda–Tanzania border, weakening basin-wide water balance calculations (World Bank, 2020).
- **On-Lake Meteorology:** Open-water climate monitoring is severely inadequate. Most meteorological stations remain land-based, yet rainfall and evaporation over the lake account for over 80% of water balance inputs and losses, introducing major uncertainty into lake level forecasting and climate response analysis where shore-based stations poorly represent lake-surface conditions (Ministry of Water, 2024).

Parameter Gaps

- **Sediment Loads:** Continuous sediment monitoring remains weak, despite pervasive soil erosion and its implications for reservoir sedimentation, navigation, and the lifespan of strategic hydropower infrastructure. While Rwanda has identified multiple sediment monitoring sites, operational long-term datasets remain limited (MoE Rwanda, 2023).
- **Groundwater Quality:** Although groundwater levels are measured in some areas, systematic groundwater quality monitoring is largely absent, even as agrochemical use intensifies and rural communities increasingly rely on shallow wells, raising the risk of diffuse aquifer contamination (Mwalimu et al., 2024).
- **Continuous Water Quality:** Monitoring is dominated by grab sampling, with very limited real-time sensing of dissolved oxygen, turbidity, or pH. This severely constrains detection of short-lived pollution events, including illegal discharges during storms or at night.

Institutional and Financial Gaps

- **Sustainability Deficit:** A persistent CAPEX–OPEX gap remains the most critical constraint. Donor-funded equipment installation is rarely matched by sustainable national financing for operation and maintenance, leading to the recurring "install–degrade–rehabilitate" cycle observed across monitoring networks.
- **Human Capacity:** There is a shortage of specialized technical staff in telemetric systems, sensor maintenance, and hydro-informatics, directly limiting the performance of modernized hydrometric networks (WRA, 2023).

Closing the above gaps will require targeted expansion in under-monitored headwaters and on-lake zones, systematic sediment and groundwater quality surveillance, wider deployment of continuous water quality sensors, and sustained financing and technical capacity for operations. Without this, basin-wide assessments will continue to rely on partial and uncertain data.

4.6.3 Data Management, Standardization, and Quality Control

Effective transboundary water management in the Lake Victoria Basin depends not only on data collection but on robust data management, harmonized standards, and credible quality control across all Partner States.

National and Regional Data Systems

Each Partner State operates its own national database, creating persistent challenges for basin-wide integration. Uganda's Water and Environment Information System (WEIS) represents the most advanced centralized platform, integrating permits, GIS, and monitoring records (MWE, 2024). Kenya manages centralized hydrological databases that archive real-time telemetric data for operational reporting (WRA, 2020). At regional level, the Lake Victoria Basin Water Information System (LVB-WIS) being developed by LVBC is intended to serve as the central aggregation platform, but full interoperability remains constrained by incompatible architectures and data formats (LVBC, 2024).

Standardization and Harmonization

The East African Community (EAC) has adopted harmonized water quality and effluent discharge standards, providing a common regulatory benchmark. However, sampling protocols, analytical methods, and enforcement practices still vary nationally, limiting direct cross-border comparability. The Nile Basin Initiative (NBI) has promoted standardized metadata, station naming, unit consistency, and data quality flags as minimum requirements for regional data sharing (NBI, 2019).

Quality Assurance and Control

Laboratory and hydrological quality control systems remain uneven. Tanzania's Mwanza laboratory has progressed toward ISO-aligned accreditation, strengthening confidence in analytical results (World Bank, 2014), while Uganda's National Water Quality Reference Laboratory serves as the national QA/QC hub (NEMA, 2024). In hydrology, outdated rating curves caused by infrequent discharge measurements remain a systemic weakness, allowing accurate water levels to be converted into unreliable flow estimates where recalibration is underfunded (WRA, 2023).

Overall Assessment

While institutional foundations for data management and standardization are now in place, weak interoperability, uneven laboratory accreditation, and under-resourced quality control systems continue to constrain basin-wide data credibility. Sustained investment in regional platforms, harmonized protocols, and routine calibration and proficiency testing is essential to ensure that monitoring data can reliably support transboundary water governance.

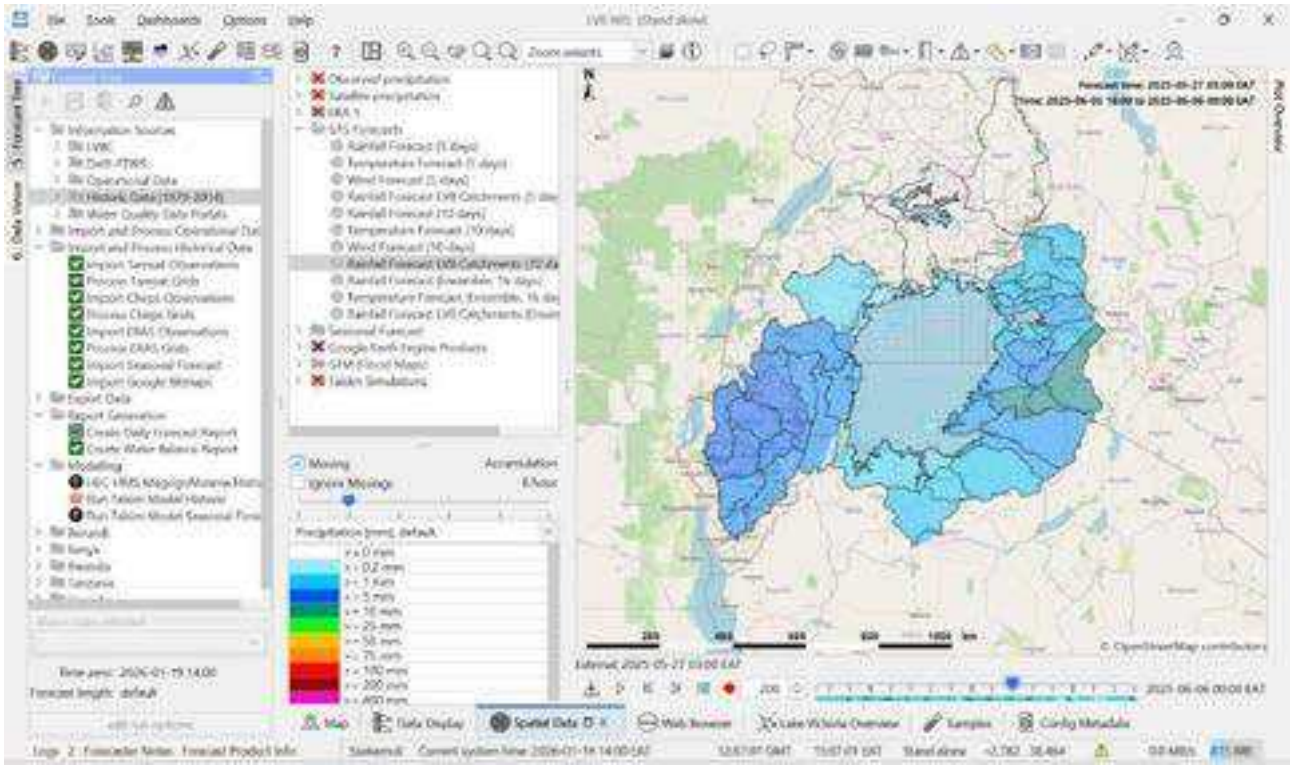


Figure 4-25. *Screenshot of the LVB-WIS System (Source LVBC).*

4.6.4 Decision Support Systems and Basin-Wide Information Platforms

The Lake Victoria Basin is transitioning from fragmented monitoring to integrated decision support, where real-time data and predictive models increasingly guide planning, flood risk management, and water allocation.

The flagship regional platform is the Lake Victoria Basin Water Information System (LVB-WIS), developed under the Lake Victoria Basin IWRM Programme with financing from BMZ/KfW (EAC, 2025; LVBC, 2024). The system integrates the Nile Basin Decision Support System (NB-DSS) for long-term strategic planning with Delft-FEWS for short-term flood forecasting, enabling both scenario analysis and operational early warning within a single framework (Sydro, 2023). By late 2024, the core system design had been validated by Partner States, and the platform entered the operationalization and national capacity-building phase (LVBC, 2025).

As part of the wider Nile Basin architecture, the NB-DSS allows countries to test trade-offs among water allocation, hydropower, irrigation, and ecosystem protection scenarios, ensuring that Lake Victoria management remains aligned with basin-wide Nile sustainability objectives (Sydro, 2023).

With rising climate variability, flood and drought early warning systems now form a critical operational layer. The Nile Flash Flood Early Warning System and Nile DEWS provide satellite-driven basin-wide alerts that are downscaled for national response (NBI, 2025). In parallel, the WMO has supported community-oriented weather forecasting, including SMS and radio dissemination for lake safety, directly benefiting fishing communities (WMO, 2024).

Overall Assessment: The LVB now possesses the core digital architecture for integrated, real-time basin decision support. The primary challenge ahead lies in fully operationalizing national linkages, sustaining model updating, and ensuring that early warning products are systematically embedded in disaster response, water allocation, and infrastructure operation. To further strengthen

last-mile connectivity and data feedback loops, mobile-based applications could be developed to facilitate decentralized data entry and access, enabling communities, extension services, and local authorities to report field conditions and retrieve advisories in real time, thereby reinforcing both the accuracy and practical utility of basin-wide information systems

4.6.5. Legal and Technical Frameworks for Transboundary Data Exchange

Transboundary data sharing in the Lake Victoria Basin is supported by a strong legal foundation, but its practical implementation remains constrained by institutional, political, and technical barriers.

The legal basis is provided by the Protocol for Sustainable Development of the Lake Victoria Basin (2003), which places a binding obligation on Partner States to exchange relevant environmental data and mandates the designation of National Focal Points to coordinate this process (EAC, 2003). At the basin wide technical level, data exchange is further guided by the Nile Basin Interim Procedures, which define operational roles for national agencies and the NBI Secretariat, and by LVBC data-sharing guidelines adopted to promote trust and safeguard national interests (NBI, 2012; World Bank, 2014).

Despite this robust framework, actual data exchange remains slow and uneven. Requests often pass through formal diplomatic channels rather than automated digital platforms, limiting their usefulness for real-time operations. Sovereignty concerns over raw hydrological data ("data nationalism") continue to inhibit full transparency, while weak technical interoperability between national databases remains a practical obstacle even where political will exists.

4.6.6 Concluding Perspectives and Future Directions

By 2025, water resources monitoring in the Lake Victoria Basin has clearly transitioned from the data collapse of the late twentieth century into a phase of digital recovery and regional re-coordination. The expansion of telemetric hydrological and meteorological networks, the operationalization of the Lake Victoria Basin Water Information System (LVB-WIS), and the revival of coordinated lake-wide water quality monitoring after two decades mark a decisive strengthening of the basin's Integrated Water Resources Management (IWRM) framework.

Yet, this recovery remains structurally uneven and financially fragile. Monitoring capacity is highly asymmetric across Partner States, with comparatively strong systems in Kenya and Rwanda contrasted by persistent weaknesses in Burundi and parts of Tanzania. Groundwater quality, sediment transport, and open-lake meteorology remain critical blind spots, while long-term sustainability is still constrained by heavy dependence on project-based financing rather than stable national O&M budgets.

Looking ahead, the strategic emphasis must shift from further network expansion toward operational sustainability, system integration, and decision relevance. Domestic financing for routine operations, harmonized standards for automated data exchange, and the full institutional embedding of LVB-WIS as a daily decision-support tool are now the central priorities. Without this transition, the growing volume of data will not translate into improved basin governance.

Several deeper structural trends shape the future of basin data management. First, the continued "projectization" of monitoring systems exposes data security to donor cycles, producing recurring booms and busts in data availability. Second, the rise of "virtual monitoring" through satellite and model-based systems offers efficiency and spatial coverage but also shifts control toward centralized technical institutions, with implications for national ownership. Third, data sharing increasingly functions as a proxy for political trust: while legal protocols are strong, real-time exchange remains sensitive, though the success of the 2025 joint lake water quality survey demonstrates that shared environmental risks can unlock cooperation. Finally, the persistent neglect of systematic groundwater quality monitoring represents an "invisible" but escalating public health and water security risk as climate variability drives greater reliance on aquifers.

In sum, the Lake Victoria Basin now possesses the core digital architecture for modern, transboundary water governance. Whether this potential is realized will depend on the political and financial commitment to sustain operations, close strategic data gaps—especially for groundwater and sediments—and firmly align data generation with real-time basin decision-making.

4.7 Key Water Resources Challenges and Strategic Responses

The Lake Victoria Basin faces interconnected water security challenges driven by climate extremes, outdated regulation, weak groundwater governance, uneven monitoring, constrained data exchange, and fragile institutional financing. Despite recent technical gains, structural vulnerabilities continue to limit long-term resilience.

Key Challenges and Priority Responses

- **Climate variability and extremes:** Intensifying floods and droughts linked to IOD/ENSO expose the lake's sensitive water balance. Recommended measures: Integrate seasonal forecasts into dam operations, apply adaptive lake level rules, strengthen flood–drought early warning, and climate-proof monitoring infrastructure.
- **Agreed Curve misalignment:** Static colonial-era outflow rules fail under both droughts and floods. Recommended measures: Modernize under a climate-adaptive framework, establish basin-wide abstraction accounting, optimize hydropower cascades, introduce benefit-sharing, and align with the CFA.
- **Groundwater governance blind spot:** Heavy reliance on groundwater with minimal monitoring and weak transboundary control. Recommended measures: Deploy telemetered groundwater networks, undertake sustainable yield assessments, regulate irrigation abstraction, and formalize cooperative aquifer management.
- **Monitoring and data system gaps:** Spatially uneven coverage and fragile O&M financing persist. Recommended measures: Densify headwater networks (especially Burundi), expand open-lake meteorology, sediment and real-time water quality monitoring, and strengthen hydro-informatics capacity.
- **Weak transboundary data exchange:** Legal frameworks exist but real-time automation remains limited. Recommended measures: Fully operationalize LVB-WIS, harmonize formats and QC standards, automate near–real-time sharing, and update rating curves routinely.
- **Spatial observation inequities:** Persistent blind spots in remote transboundary catchments and wetlands undermine basin accounting. Recommended measures: Target data-poor upstream areas, expand wetland monitoring, integrate satellite Earth observation, and implement equitable cost-sharing.
- **Surface water–groundwater disconnection:** Fragmented management weakens natural buffering and accelerates pollution transfer. Recommended measures: Protect recharge zones, monitor exchange in wetlands, apply conjunctive use planning, and control pollution at source.
- **Institutional and financial fragility:** Project dependence undermines maintenance and data continuity. Recommended measures: Stabilize national budget allocations, establish dedicated maintenance funds, introduce beneficiary-based cost recovery, and create regional calibration centers.
- **Emerging water quality threats:** Pesticides, metals, hydrocarbons, and pharmaceuticals are rising while analytical capacity remains weak. Recommended measures: Strengthen ISO-accredited laboratories, invest in advanced equipment, train technicians, and form regional centers of excellence.
- **Climate change intensification:** Warming, shifting rainfall and lake stratification threaten water availability, fisheries, and oxygen dynamics. Recommended measures: Mainstream climate projections into planning, expand ecosystem-based adaptation, strengthen hydrological and lake-ecology modeling, and climate services.



Chapter 5

WATER QUALITY

SUMMARY - CHAPTER 5

Chapter 5 presents a comprehensive assessment of the state of water quality in the Lake Victoria Basin (LVB). It documents the socio-economic importance of the basin's waters, identifies the major drivers and sources of pollution, and examines the ecological and human health impacts of declining water quality. The chapter integrates both field data and satellite monitoring to establish a robust baseline for informed management and policy action aimed at protecting and restoring water quality in the LVB.



Rivers, Groundwater and General Water Quality

Although rivers provide only ~20% of inflows to Lake Victoria, they carry a large share of nutrients, sediments, and pollutants, making them a major source of water quality decline.



Physical Limnology: The Primary Driver of Water Quality

Lake Victoria is a warm monomictic lake, meaning it remains stratified most of the year but mixes fully once annually (June–August).



Impacts of Water Quality Degradation

Water quality decline has fundamentally altered the lake's ecology: Persistent nutrient loading has caused widespread eutrophication, leading to frequent oxygen depletion in deep waters and the dominance of harmful cyanobacteria.

Public health impacts include fishing communities in Uganda accounting for ~58% of national cholera cases, while cyanobacteria toxins often exceed WHO safety limits by 274 times.

Key Messages

Rivers, Groundwater and General Water Quality

1. **Over four decades, water quality in the water bodies in the Lake Victoria Basin (LVB)** has deteriorated sharply due to range of anthropogenic pressures, including untreated sewage, industrial effluents, farm runoff, and land degradation. These pressures have undermined biodiversity, public health, and regional economic stability.
2. **Major rivers such as the Kagera, Nyando, Nzoia, Sondu-Miriu, Mara, and Simiyu** are highly turbid, oxygen-depleted, and nutrient-rich, transporting large loads of sediments, pollutants, and pathogens—including *E. coli*, *Salmonella*, and *Vibrio cholerae*. Although rivers contribute only about 20% of Lake Victoria's inflows, they deliver a disproportionate share of nutrients and contaminants, making them a principal driver of water quality decline and a significant threat to both human and ecosystem health.
3. **Groundwater—the main sources of drinking water in rural areas**—faces contamination from nitrates near farms and pit latrines. Naturally occurring minerals such as iron, fluoride and arsenic further affect groundwater quality in some regions.

Physical Limnology: The Primary Driver of Water Quality

4. **Lake Victoria is a warm monomictic lake, meaning it remains stratified** most of the year but mixes fully once annually (June–August). During stratification, the deep waters become oxygen depleted, forming extensive "dead zones" that now cover approximately 40% of the lake bottom.
5. **Oxygen depletion triggers the release of phosphorus** and other reduced compounds from bottom sediments. This process sustains a self-perpetuating eutrophication cycle, promoting excessive algal blooms, further oxygen depletion, and ecological disruption during annual mixing periods.

Spatial Patterns and Temporal Fluctuations in Lake Water Quality

6. **Satellite and field monitoring/observations reveal a pronounced belt of** heavily polluted water surrounding much of the shoreline, with semi-enclosed gulfs (Winam, Murchison, Mwanza) serving as nutrient traps where harmful algal blooms concentrate.
7. **Rainfall seasons drive spikes in pollutant** and nutrient loads into the lake; algal blooms typically follow these events once sediments settle and light conditions improve.
8. **Divergent recovery patterns are emerging:** Offshore waters show partial recovery with Secchi depth increasing from <2m to 3-4m, and chlorophyll-a declining from ~14 µg/L to ~3 µg/L). In contrast, nearshore waters continue to deteriorate due to extreme nutrient enrichment—some bays showing phosphorus increases from 0.05 mg/L to over 1.4 mg/L.
9. **Despite nutrient saturation, algal biomass** has declined compared to the 1990s peaks, likely due to stronger wind-driven mixing that reduces light available for algal growth.

Drivers and Sources of Pollution

10. **Rapid population growth, unplanned urbanization, agricultural expansion,** and poor waste management are the primary drivers of pollution in the LVB. These drivers generate mounting pressures on the basin's ecosystems through the discharge of untreated wastewater, and the widespread dumping of uncollected solid waste into rivers and the lake. Industrial and mining effluents release heavy metals and mercury, while deforestation and cultivation on steep slopes accelerate erosion and nutrient runoff, delivering about three million tonnes of sediment annually. In addition, atmospheric deposition, plastics, and e-waste—estimated at 128 kilotonnes each year—introduce Persistent Organic Pollutants and other toxins, further degrading water quality and ecosystem health.

Impacts of Water Quality Degradation

11. **The decline of water quality has fundamentally altered the lake's ecology:** persistent nutrient loading has caused widespread eutrophication, leading to frequent oxygen depletion in deep waters and the dominance of harmful cyanobacteria. These changes have disrupted the natural food web, reduced fish habitat, and weakened the overall stability and resilience of the lake ecosystem.
12. **Economic losses are substantial and crosscutting:** Lake-wide, restoring water quality is estimated to require US$10 billion over ten years, underscoring the scale of current and projected losses. The most affected sectors are fisheries (US$500–600 million industry), tourism and recreation (losses in the millions annually due to algal blooms deterring visitors and recreation), drinking water supply (utilities incurring millions in extra treatment costs and capital investments), and real estate (falling shoreline property values).

13. Public health impacts are severe, with fishing communities in Uganda accounting for about 58% of the country's cholera cases, and cyanobacterial toxin levels exceeding WHO safety limits by up to 274 times.

Regional and National Governance of Water Quality

14. **Regional governance is binding but operationally weak:** The 2003 Protocol for the Sustainable Development of the Lake Victoria Basin, ratified by all Partner States, mandates LVBC to coordinate pollution control and harmonization. However, the region lacks binding operational tools—such as a water-quality data-sharing protocol with defined parameters, reporting, and QA/QC—while implementation of EAC effluent discharge standards remains uneven across countries.
15. **Weak enforcement of national policies and regulations:** All five Partner States have modern water and environmental laws, and some have specific effluent discharge regulations. However, enforcement is hindered by chronic underfunding of environmental agencies, insufficient staffing, corruption, and limited laboratory and inspection capacity. This results in widespread non-compliance by industries, municipalities, and farms, with very few penalties imposed.
16. **Monitoring networks and laboratories underpowered:** National agencies and research institutions maintain water quality monitoring sites and laboratories, but coverage is fragmented and inconsistent across the basin. Many labs face shortages of reagents, equipment maintenance backlogs, and lack of accreditation. Monitoring campaigns are often project-dependent, leading to data gaps once external funding ends. As a result, long-term trend analysis and cross-country comparisons remain weak.
17. **Past programmes created momentum, but basin remains fragile:** The Lake Victoria Environmental Management Project (LVEMP I & II) generated valuable data, piloted wastewater and wetland interventions, and built some institutional capacity. Current LVBC-led initiatives, such as the Integrated Water Resources Management (IWRM) Programme and the Lake Victoria Basin Water Information System (LVB-WIS), are expanding basin-wide data sharing and priority investment planning. However, these achievements remain donor-dependent and require stronger political commitment and sustainable financing to avoid collapse once project cycles end.

Future Outlook and Recommendations

18. **Two possible paths:** If current practices continue (Business-as-Usual), pollution and ecosystem decline will worsen. If countries act together with targeted investments (Sustainable Investment), water quality can be stabilized and improved. Rapid, harmonized policy action and sustained investments can determine whether the lake recovers or becomes locked into long-term decline.
19. **Climate change will worsen existing problems:** Heavier rain will wash more sediments and nutrients into the lake; droughts will concentrate pollutants in shrinking water bodies; warmer surface waters will promote harmful algal blooms and expand oxygen-depleted zones.
20. **Population mobility adds extra stress:** By 2050, an estimated ~38.5 million internal climate migrants may settle within the five Partner States, many near Lake Victoria, further straining resources and increasing pollution risks.

21. Priority actions:

- **a.** Invest in wastewater treatment and solid waste management for cities and towns;
- **b.** reduce agricultural runoff through soil conservation and sustainable farming;
- **c.** strengthen basin-wide monitoring with harmonized standards; and
- **d.** secure long-term financing through government budgets and climate funds while enhancing LVBC enforcement powers.



Scientists collecting samples for phytoplankton analysis during the LVBC joint cruise of Lake Victoria held in Jun-Jul 2025.

Key State Indicators – Water Resources Management and Development (2025)

Strategic & Thematic Areas	Indicator / Metric	Value / Range (2025)
W2 Water quality		
W2.1 Surface water quality (rivers and wetlands)	Total nitrogen (TN) load	~38,828 tonnes/year
	Total phosphorus (TP) load	~9,270 tonnes/year
W2.2 Groundwater quality	Status of groundwater quality	No data
W2.3 Lakes (Lake Victoria)	Secchi depth – nearshore	0.7–3.2 m
	Secchi depth – offshore	1.2–5.5 m
	Turbidity – nearshore	2.8–10.5 NTU
	Turbidity – offshore	2.6–10.5 NTU
	Chlorophyll-a – nearshore	70–80 µg/L
	Chlorophyll-a – offshore	1.5–35 µg/L
	Dissolved oxygen (wet season) – near-shore	4.2–5.8 mg O_2/L
	Dissolved oxygen (wet season) – offshore	3.6–5.8 mg O_2/L
	Total nitrogen – nearshore	Up to >10 mg/L
	Total nitrogen – offshore	0.5–0.8 mg/L
	Total phosphorus – nearshore	0.1–0.3 mg/L
	Total phosphorus – offshore	0.05–0.07 mg/L
	Dissolved silica – nearshore	2–3 mg/L (up to ~15 mg/L near inflows)
	Dissolved silica – offshore	1–2 mg/L

5.1 Introduction: A Vital Resource Under Threat

Chapter 5 opens by framing Lake Victoria as both an ecological gem and an economic lifeline for over 45 million people living within its basin. It highlights the urgency of the water quality crisis, showing how decades of untreated wastewater, agricultural runoff, and land degradation have destabilized ecosystems, eroded biodiversity, and threatened livelihoods. The **Section 5.1** highlights the dual character of the problem—scientific and socio-economic—while underscoring the current information gaps that hinder effective policy responses. By presenting water quality decline as both an environmental emergency and a developmental challenge, the introduction prepares the reader for the chapter's deeper analysis of pollution drivers, ecological impacts, economic costs, and future management pathways.

5.1.1 Introduction: A Vital Resource Under Threat

Lake Victoria, the world's largest tropical lake, lies at the heart of a transboundary ecosystem that directly sustains over 45 million people across Burundi, Kenya, Rwanda, Tanzania, and Uganda. However, this vital resource is experiencing severe water quality deterioration that threatens the fundamental ecological processes upon which the entire basin depends.

Over the past four decades, the basin has witnessed precipitous decline in water quality driven by agricultural runoff, untreated municipal wastewater, industrial effluent, and widespread land degradation (Ali et al., 2024; Awange et al., 2019). This degradation has triggered cascading ecological consequences, including cultural eutrophication, widespread hypoxia, the loss of native biodiversity, declining fish stocks, and rising public health risks (Aloyce et al., 2001; Bastiancich et al., 2022).

Once home to over 500 endemic cichlid species, the system has lost approximately half of its native biodiversity, with the International Union for Conservation of Nature (IUCN) considering 76% of remaining endemic species threatened with extinction. Simultaneously, the world's second most productive freshwater fishery—valued at approximately US$600 million annually—faces unprecedented challenges from habitat degradation, periodic mass fish kills, and the expansion of oxygen-depleted "dead zones" (Antillón et al., 2017).

Despite the critical importance of understanding these changes, comprehensive and current information on water quality across the basin remains fragmented and inadequate. This knowledge gap severely hampers evidence-based policymaking and strategic investment decisions needed to address the crisis. The lack of integrated, basin-wide assessment limits the ability of governments, development partners, and communities to implement effective interventions and coordinate transboundary responses.

5.1.2 Chapter purpose and approach

This chapter closes a critical information gap by delivering a comprehensive, evidence-based assessment of water quality in the Lake Victoria Basin. It is organized into three core components:

- **Current State Assessment** (Section 5.2–5.4) examines rivers, catchments, and groundwater, and analyses Lake Victoria's hydrodynamics and thermal stratification that drive hypoxia. Using both remote sensing and ground observations, it maps spatial and temporal water quality patterns, highlighting pollution hotspots and seasonal trends.

- **Drivers and Impacts** (Sections 5.5–5.6) identify and quantify point and non-point pollution sources and assess their ecological, economic, and human health consequences.
- **Management and Outlook** (Sections 5.7–5.8) review governance frameworks, institutional capacity, and ongoing interventions, concluding with projected scenarios, key gaps, and strategic recommendations.

The assessment integrates traditional monitoring with advanced Earth observation, linking basin-wide trends to local processes. Emphasis is placed on the lake's annual stratification cycle, which shapes oxygen dynamics, nutrient fluxes, and ecosystem health.

By providing a rigorous, cross-border evidence base, this chapter supports informed decision-making and coordinated management, guiding initiatives such as the Lakewide Inclusive Sanitation (LWIS) Strategy and broader regional policy actions for sustainable stewardship of Lake Victoria (Ali et al., 2024; Batina & Krtalić, 2024).

5.2 Ambient Water Quality of Rivers and Groundwater

Water quality degradation in the Lake Victoria Basin is widespread, extending from upper catchments to the open lake. Rivers rapidly transmit catchment pressures—showing sharp spatial (urban/industrial vs. agricultural vs. wetland-buffered) and seasonal ("first-flush" wet-season vs. concentrated dry-season) contrasts. Groundwater— often overlooked despite its importance for rural communities —faces rising risks from both natural geochemical factors and human activities. Together, these assessments show how pollutants enter the lake, the severity and variability of contamination, and the growing mix of traditional and emerging pollutants shaping the basin's aquatic environment.

5.2.1 Spatial and Temporal River Water Quality Variation

Water quality across the Lake Victoria Basin (LVB) displays pronounced spatial and temporal variability, shaped by the complex interplay of geology, land use, hydrology, and human activity. Pristine headwaters draining forested uplands exhibit clear, well-oxygenated waters with low mineralization and sediment loads, whereas rivers flowing through agricultural, urban, and mining zones show severe degradation marked by high turbidity, nutrient enrichment, organic pollution, and heavy metal contamination. Seasonal rainfall patterns amplify these contrasts: wet seasons trigger intense runoff and "first flush" pollution events, while dry seasons concentrate dissolved solids under low-flow conditions. The following subsections examine key physical, chemical, and biological parameters governing these variations—highlighting how natural processes and anthropogenic pressures combine to define the water quality regimes of the basin's diverse river systems.

5.2.1.1 Physical Parameters

The physical characteristics of rivers in the Lake Victoria Basin (LVB) provide the most immediate evidence of environmental stress and landscape disturbance. Clear, well-oxygenated headwaters give way to turbid, coloured, and oxygen-depleted rivers in degraded and urbanized catchments. Variations in turbidity, colour, pH, conductivity, and dissolved oxygen reflect both natural geochemical conditions and increasing human pressures, making these parameters key indicators of the basin's changing water quality. Key patterns include:

- **Turbidity:** urbidity remains a defining indicator of catchment degradation. While clear, forested headwaters such as the upper Sondu-Miriu and Yala maintain <30 NTU, urban and industrial rivers exhibit extreme cloudiness. Wet-season peaks reach 482 NTU in the Sio River near Busia from sewage and mining runoff (Nyaboga et al., 2019) and up to 6,000 NTU in the Mara River, where flash floods and bank erosion mobilize vast sediment loads (Dutton et al., 2018). Mining-impacted Kitengure streams reach 257 NTU, while the Rwizi in Mbarara regularly exceeds 200 NTU during urban storm flows (Atwebembeire et al., 2019). The pattern confirms that rivers draining urban, mining, and intensively farmed catchments experience the highest turbidity across the basin.
- **Color:** River waters entering Lake Victoria range from naturally "tea-stained" hues to intensely polluted black or orange tones. The Yala River shows extreme colouration—up to 9,210 Pt-Co—caused by reddish-orange effluent from tea-processing industries (Maghanga et al., 2009). Kitengure streams in Uganda (924–1,576 Pt-Co) are similarly discoloured by suspended and dissolved solids from artisanal gold mining (Kaggwa et al., 2024). The Nyando and Rwizi–Bukora rivers (>800 Pt-Co) are strongly stained by agricultural runoff and municipal discharges (Ojok et al., 2017), while the Kagera shows moderate colour (118–145 Pt-Co) from humic matter and eroded sediments (Mpakicol et al., 2023). In contrast, the Mara–Grumeti rivers darken naturally due to decomposing vegetation and hippopotamus dung releasing coloured organic matter (Subalusky et al., 2018). Urban rivers such as Kisat and Nyashishi often turn black or dark brown from untreated sewage and tannery effluents (Ondiek et al., 2020; NEMC, 2023).
- **pH:** Ranges widely (5.0–9.3). The Kagera River remains slightly acidic (5.0–6.5) due to drainage of an area of crystalline basement rocks and highly weathered lateritic soils with low buffering capacity, coupled with humic and fulvic acids released from dense riparian vegetation and wetlands. In contrast, the Nyando River is more alkaline (7.0–8.0), flowing through carbonate-rich or volcanic (basalt) formations that release calcium, magnesium, and bicarbonate ions, providing strong buffering capacity (Nannyonjo et al., 2023; Ondoo et al., 2019).
- **Alkalinity and Hardness**: Rivers across the Lake Victoria Basin vary widely in alkalinity and hardness, shaped by geology and pollution. Highland rivers such as the Nyando and Yala, draining ancient crystalline rocks, are naturally soft (<60 mg/L $CaCO_3$) with low alkalinity. In contrast, the Mara and Grumeti rivers are hard and alkaline due to calcium- and magnesium-rich volcanic soils of the Serengeti. The Rwizi–Bukora and Kagera rivers show moderate hardness (≈50–100 mg/L $CaCO_3$) from mixed geological and agricultural influences (Mpakicol et al., 2023). Urban drains like the Kisat exhibit high alkalinity (~150 mg/L $CaCO_3$) from untreated sewage and industrial effluents (Ondiek et al., 2020). Overall, geology dictates the basin's natural mineral balance, while pollution amplifies

alkalinity in urbanized systems.

- **Electrical Conductivity (EC) and Total Dissolved Solids (TDS):** EC and TDS vary widely among rivers draining into Lake Victoria, reflecting geological contrasts and human pressures. Low values occur in forested highland rivers like the Yala (20–99 µS/cm) due to low mineralization (Kithiia, 2015), while very high levels in the Grumeti (>3,000 µS/cm; >2,000 mg/L) and Mara (>2,000 µS/cm; >1,300 mg/L) arise from alkaline geology and evaporative concentration (M'Kandawire et al., 2018). The Kagera shows moderate values (95–380 µS/cm; 60–240 mg/L), buffered by extensive wetlands (Odong et al., 2015). Elevated readings in urban rivers like the Kisat result from industrial effluents (Ondiek et al., 2020), while moderate enrichment in the Nyando reflects agricultural and domestic inputs (Ondoo et al., 2019). Overall, EC and TDS patterns highlight the combined influence of geology, climate, and land use across the basin.
- **Dissolved Oxygen (DO):** DO levels vary widely across rivers entering Lake Victoria, with severe depletion (<3 mg/L) common in urban and agricultural streams where high BOD and COD from sewage and organic waste suppress aquatic life. Fast-flowing upland rivers like the upper Mara and Rwizi maintain near-saturation levels (>7 mg/L), while polluted or sluggish sections—such as the Kisat (3.4–5.9 mg/L), Yala (~3.7 mg/L), and Nyando (1.5–3.1 mg/L)—often fall below the 5 mg/L threshold for aquatic life (Ondiek et al., 2020; Ondiek et al., 2024; Ondoo et al., 2019). In the Mara and Grumeti, decomposition of hippopotamus dung causes nocturnal hypoxia, offset by daytime algal supersaturation (Dutton et al., 2022). The Rwizi shows a similar decline from oxygen-rich headwaters (~9.9 mg/L) to hypoxic downstream plains (<5 mg/L) as urban and agricultural pressures increase (Atwebembeire et al., 2018). Overall, DO patterns reflect a shift from well-oxygenated uplands to oxygen-poor lowlands, driven by organic loading and reduced flow.

5.2.1.2 Sediment Transport By Rivers

Sediment is the dominant pollutant by volume in the Lake Victoria Basin (LVB), acting both as a contaminant and as a carrier for nutrients, pesticides, and metals. The concentration of suspended solids and the total annual sediment load of rivers vary markedly across the basin, shaped primarily by land use, topography, and rainfall intensity. Overall, about 65–75 percent of the lake's total sediment load is delivered by just four rivers – the Nzoia, Nyando, Yala and Kagera Rivers, which together contribute roughly 7.3 million tons per year (see **Table 5-1** below), underscoring the outsized role of a few highly disturbed catchments in basin sedimentation dynamics.

Spatially, there is a clear and extreme divide:

- **Pristine Headwaters**: Forested, high-altitude headwaters such as the upper Sondu-Miriu maintain clear water with very low Total Suspended Solids (TSS) (Koech et al., 2022).
- **Agricultural "Hotspots":** Steep terrain catchments that are deforested and under intensive cultivation—especially the Nzoia, Nyando, and Yala—experience severe soil erosion and surface runoff, producing the basin's largest sediment loads and accounting for most material entering the lake (World Bank, 2016).
- **Moderate-Yield Catchments**: Rivers such as the Rwizi, Sondu-Miriu, and Gucha-Migori export 400 000–500 000 tons annually, reflecting intermediate disturbance levels and variable rainfall.
- **Wetland-Dominated Rivers**: ystems like the Kagera and Katonga traverse extensive wetlands that trap fine materials, thus reducing the sediment ultimately delivered to the lake.

- **Low-Yield Rivers**: Sio, Awach, Mara, and Simiyu generally deliver < 250 000 tons per year owing to gentler relief, more stable land cover, and lower runoff intensities.
- **Urban/Industrial Channels**: Small, urban rivers like the Nakivubo, Nyashishi and Kisat carry a complex mix of industrial effluent and domestic sewage, contributing high loads of both inorganic and organic solids (CSE, 2023).
- **Natural/Episodic Rivers**: In semi-arid zones such as the Serengeti, ephemeral rivers like Grumeti exhibit episodic sediment pulses during flash floods, amplified by wildlife-induced resuspension in dry-season pools.

Temporally, sediment transport is strongly seasonal. Concentrations and loads are minimal during the dry season and surge to extreme levels during the rains, when intense runoff mobilizes eroded topsoil, nutrients, and urban debris. These "first-flush" events dominate annual loads, accounting for the high inter-annual variability observed in the rivers.

The estimated sediment concentrations and annual loads of key rivers are summarized in **Table 5-1**, and the aggregate contributions are illustrated in **Figure 5-1**.

Table 5-1. Estimated Sediment Concentrations and Annual Sediment Loads of Key Rivers

River	Suspended Sediment Concentration	Annual Sediment Load / Yield (tons/ year)	Source(s)
Kagera River (Burundi, Rwanda/ Tanzania/ Uganda)	~20-32 mg/L in dry season	~1,400,000	NBI (2012, Kagera Basin Feasibility).
Rwizi River (Uganda)	20-30 mg/L in dry season; 182 mg/L in wet season	~500,000	MWE (2021, Rwizi WQ monitoring); Atwebembeire et al., 2019.
Katonga River (Uganda)	Low TSS concentrations, lower than other Uganda catchments	Low, no quantitative figures	
Nzoia River (Kenya)	~230-455 mg/L wet season peaks	~2,500,000	Kipng'etich et al., 2017; World Bank, 2016.
Nyando River (Kenya)	65-80 mg/L in dry season; 124 mg/L in wet season	1,400,000	Walsh et al., 2004; Misigo & Suzuki, 2018
Yala (Kenya)	Low in headwaters; very high downstream	~2,000,000	Kithiia, 2012
Sondu-Miriu River (Kenya)	25–496 mg/L	~552,000	Koech et al., 2022; Misigo & Suzuki, 2018.
Sio River (Kenya)	20-50 mg/L in dry season; 200-600 mg/L in rain season.	~87,800	CaPNex, 2019
Awach River (Kenya)	578 mg/L in rain season (Awach-Kiboun)	~120,000	Misigo & Suzuki, 2018.
Gucha-Migori River (Kenya)	60-325.5 mg/L	~400,000	JICA, 2015
Mara River (Kenya,Tanzania)	10-30 mg/L in dry season; 268-285 mg/L in wet season.	~253,000	Dutton et al., 2018; WREM International, 2008

River	Suspended Sediment Concentration	Annual Sediment Load / Yield (tons/ year)	Source(s)
Grumeti River (Tanzania)	Dominated by flash flood pulses; hippo resuspension in pools	Lower than Mara; no robust annual figure	McNaughton, 2008.
Simiyu River (Tanzania)	Close to 0 mg/L (dry season); 109 mg/L in rain season. Muddy floods (>1000 mg/L) are common in rainy months	~98,500	Kimwaga et al., 2012
Nyashishi (Tanzania) (incl. Kisat, Kenya)	High TSS/organic solids near outfalls	Not robustly quantified (point source dominated)	CSE, 2023

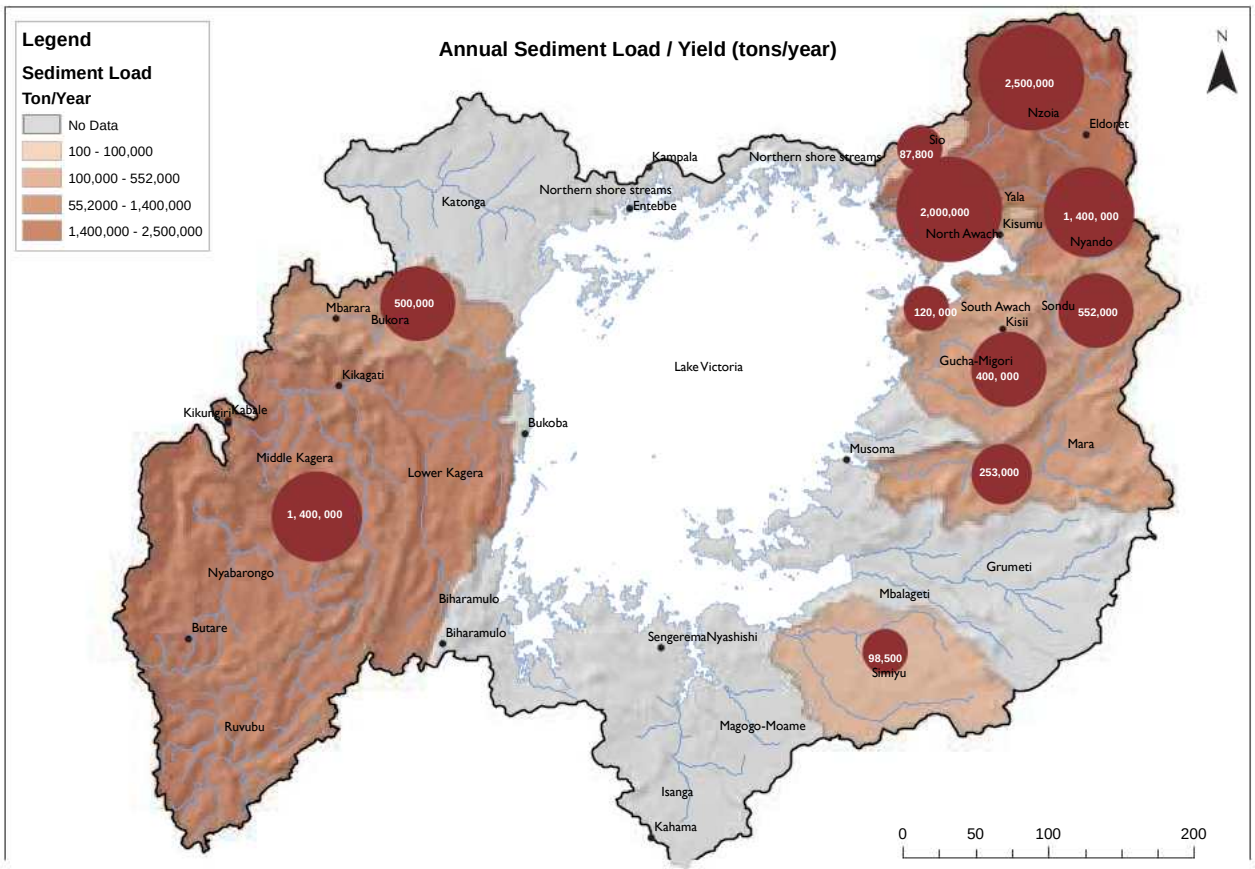


Figure 5-1. *Sediment load by key rivers that drain into Lake Victoria (prepared from sources compiled in Table 5-1).*

5.2.1.3 Nutrients and Contamination in Rivers

Key contaminants conveyed by rivers include the following:

- **Nutrients (N & P)**: Rivers entering Lake Victoria show strong spatial and temporal variability in nutrient levels, forming three main categories. **(1) Anthropogenic hotspots**—rivers draining urban or intensively farmed areas—record extremely high concentrations, including Nyashishi (TP ≈ 2.396 mg/L), Kisat (TN ≈ 0.885 mg/L), Nyando (TN 1.32–9.98 mg/L; TP 0.25–2.91 mg/L), and Yala (TP 51–490 µg/L) (Ministry of Water, 2023; Ondiek et al., 2020; Kithiia, 2015). **(2) Natural hotspots**—such as the Mara and Grumeti—show naturally elevated nutrients from mineral-rich soils and wildlife inputs, notably hippopotamus dung (Dutton et al., 2022). **(3) Mixed-use basins**—like the Kagera—combine multiple sources, producing moderate but significant loads, with nitrate levels of 0.004–3.31 mg/L and isotopic evidence showing 49–73% of nitrogen from manure and sewage (Mathenge et al., 2025). Nutrient levels are lowest in forested headwaters and rise sharply downstream through agricultural and urban zones, peaking during wet seasons as runoff carries fertilizers, sewage, and sediment into waterways.
- **Microbiological Contamination**: Microbial pollution in the Lake Victoria Basin is widespread, with E. coli, fecal coliforms, and pathogens far exceeding WHO and national limits. Urban rivers—Nakivubo, Kisat (5.2×10^5 MPN/100 mL), and Nyashishi—act as open sewers for Kampala, Kisumu, and Mwanza, carrying untreated sewage and industrial effluent (Ondiek et al., 2020; NEMC, 2023). Agricultural rivers such as the Yala and Rwizi show heavy fecal contamination from manure, sanitation failures, and runoff. Pathogens like Salmonella spp. (18.5%) and Vibrio cholerae (5.4%) are reported in Kenyan tributaries, linking pollution to recurring cholera and typhoid outbreaks (Okoth et al., 2022). Water quality drops sharply from clean headwaters such as the Grumeti (<2 CFU/100 mL) to polluted lowlands (Elisante & Muzuka, 2016). Contamination peaks in rainy seasons as runoff flushes fecal waste from latrines, livestock, and drains (Ijiro et al., 2023). In contrast, wetland-buffered systems like the Katonga remain relatively clean, underscoring the vital filtration role of papyrus wetlands (LVBC, 2017).
- **Organic Matter and Carbon Dynamics**: Rivers in the Lake Victoria Basin carry highly variable organic loads that shape oxygen depletion, nutrient cycling, and ecosystem health. Urban streams like Nakivubo and Kisat show extreme pollution, with BOD_5 exceeding 100–300mg/L and COD 250–600 mg/L—levels typical of untreated wastewater (Ondiek et al., 2020). The Nyashishi River records even higher industrial loads (BOD_5 > 1,200 mg/L; COD > 2,000 mg/L) (NEMC, 2023). Agricultural rivers such as Nyando, Yala, and Nzoia exhibit moderate enrichment (BOD 10–20 mg/L; COD 20–40 mg/L; TOC ≈ 15 mg/L) mainly from soil erosion and agro-processing waste (Tamooh et al., 2012). The Rwizi shows a sharp rise from <5 mg/L in forested headwaters to ~34 mg/L downstream of Mbarara. Wetland systems like Katonga maintain low BOD_5 and COD but export high dissolved organic carbon (DOC ≈ 6–8 mg/L) from decaying papyrus while trapping particulate carbon (Saunders et al., 2012). The Kagera carries moderate TOC (~24 mg/L) and DOC from wetland outflows (Mpakicol et al., 2023), while the Mara naturally enriches from hippo pools, raising BOD from 2.2 mg/L to ~26 mg/L and DOC from ~2.7 mg/L to ~5 mg/L (Subalusky et al., 2018). Basin-wide, organic loads peak in the wet season as runoff mobilizes dissolved and particulate carbon.
- **Plastics & Microplastics**: Plastic and microplastic pollution is a growing environmental threat in the Lake Victoria Basin, with rivers acting as major conduits

plastic debris into the lake. Concentrations are highest in urban and industrial catchments—Nakivubo Channel (1,568 ± 1,473 to 2,140 ± 3,670 particles m^{-3}), Kisat (~1,230 ± 620 particles m^{-3}), and Nyashishi–Mirongo (~940–1,520 particles m^{-3})—while agricultural rivers like the Nzoia show lower levels (~420–810 particles m^{-3}) (Egessa et al., 2020). Most are secondary microplastics, dominated by fibres from textiles, laundry effluent, and fishing gear, and fragments from degraded bottles, bags, and packaging. Major sources include urban runoff, agricultural plastics, and fishing activities, with polyethylene and polypropylene most prevalent. Concentrations rise during wet seasons as runoff mobilizes land-based litter and remain high in stagnant urban drains during dry periods. Overall, LVB rivers are heavily contaminated, highlighting the urgent need for improved waste management, stricter plastic controls, and coordinated basin-wide monitoring

- **Heavy Metals in Water and Sediment**: Heavy metal pollution in the Lake Victoria Basin is severe but highly localized, concentrated in urban, industrial, and mining zones. Urban rivers such as Nakivubo (Cu = 3.3 mg/L; Cd = 0.14 mg/L; Pb = 3.0 mg/L) and Kisat (Pb = 1,188 mg/kg; Cu = 259 mg/kg) receive untreated effluents, creating extreme hotspots (Fuhrimann et al., 2015; Mbabazi et al., 2024). In Mwanza, sediments show elevated Pb and Cd from industrial discharge, while mining areas like Kitengure record the highest levels—Hg up to 36,300 mg/kg and As = 985 mg/kg from artisanal gold processing (Kaggwa et al., 2024). Rivers such as Mara, Sio, and Nzoia show multi-metal contamination from mining and agriculture, with Pb, Cr, and Cd exceeding WHO limits (M'Kandawire et al., 2018; Okeyo et al., 2022; Munyao et al., 2017). Contamination rises during wet seasons with runoff, but peaks in dry months in urban and mining areas due to poor dilution (Mpakicol et al., 2023). Wetlands and bays like Inner Murchison Bay and Katonga act as metal sinks, accumulating levels above ecological thresholds (LVBC, 2017).

- **Hazardous Waste, POPs, and E-waste Contamination**: Hazardous pollutants—including Persistent Organic Pollutants (POPs) and e-waste derivatives—pose a growing challenge in the Lake Victoria Basin, concentrated mainly in urban and industrial rivers. In Kampala's Nakivubo Channel, PBDEs in sediments reach 127–5,500 µg/kg and PCBs in water up to 106 ng/L, reflecting industrial and sewage discharges. Informal e-waste recycling releases additional POPs and heavy metals through open burning and dismantling (Ssebugere et al., 2013, 2019; Fuhrimann et al., 2016). Downstream, Murchison Bay shows ΣPCDD/Fs in fish of 5–49 pg g**Note:** The point source TN and TP figures from LVEMP (2005) appear exceptionally low and likely represent only a fraction of the total point sources quantified in that specific study. They are included for consistency but should be interpreted as a significant underestimate of the true point source load.

- [1] ww and ΣPBDEs in sediments of 61–179 pg g^{-1} dw, confirming its role as a pollutant sink (Ssebugere et al., 2014; Zhu et al., 2014). In Mwanza Gulf, PCB-laden effluent (0.95–2.24 µg/L in water; up to 10.3 µg/kg dw in sediments) mirrors similar contamination in Kenya's Winam Gulf, where OCPs and metals accumulate (Wenaty et al., 2019; Ogendi et al., 2018). Agricultural basins like Nzoia and Yala remain pesticide hotspots, dominated by DDTs (≤8.7 µg/kg) and lindane (≤1.8 µg/kg) (K'Oreje et al., 2012). POP and pesticide levels rise during wet seasons from runoff, while dry-season peaks occur in urban drains due to limited dilution (Fuhrimann et al., 2016).

- **Emerging Contaminants**: Rivers in the Lake Victoria Basin are increasingly polluted by emerging contaminants—pharmaceuticals,

personal care products, modern pesticides, and industrial compounds such as Per- and Polyfluoroalkyl Substances (PFAS)—that pose growing ecological and health risks. Urban catchments like Nakivubo (Kampala) and Kisat (Kisumu) discharge untreated municipal, hospital, and industrial wastewater containing sulfamethoxazole (≤5,600 ng/L), carbamazepine (72 ng/L), diclofenac (160 ng/L), and PFAS (23.8 ng/L) (Nantaba et al., 2020; K'Oreje et al., 2020; Arinaitwe et al., 2021). In agricultural zones such as the Nzoia Basin, nevirapine reaches 700 ng/L and herbicides (atrazine, diuron, alachlor) 0.14–1.75 µg/L (K'Oreje et al., 2022). These pollutants arise mainly from effluent, hospital waste, and agricultural runoff. Persistent exposure contributes to antimicrobial resistance, with high E. coli resistance observed among lakeshore communities (Kabiswa et al., 2025). PFAS, detected in rivers like the Kagera and Sio, bioaccumulate even at low ng/L levels, while currently used pesticides remain a continuing toxicological concern (Arinaitwe et al., 2021).

5.2.1.4 Seasonal Dynamics in Riverine Water Quality

River water quality in the Lake Victoria Basin follows a pronounced seasonal cycle driven by the bimodal rains.

- **Wet seasons (Mar–May; Sep–Nov)** Heavy rains generate intense runoff and a strong "first-flush" that mobilizes sediments, nutrients, organic matter, microbes, plastics, and contaminants from fields and urban areas. Turbidity rises sharply—rivers turn "earthen brown"(**Figure 5-2**)—with extreme values in the Mara (~6,000 NTU), Sio (~482 NTU), and mining-impacted Kitengure (148–257 NTU) (Dutton et al., 2018; Nyaboga et al., 2019; Kaggwa et al., 2024). Suspended solids peak across agricultural hotspots such as the Nzoia, Nyando, and Yala, while wetlands like the Kagera and Katonga trap and attenuate loads (World Bank, 2016). Nutrient and oxygen demand also surge: runoff elevates TP, TN, BOD, and COD (e.g., Nyando TN 1.32–9.98 mg/L; TP 0.25–2.91 mg/L; Kisat BOD >100–300 mg/L; COD 250–600+ mg/L) (Ondiek et al., 2020). Bacteriological contamination intensifies as animal and human wastes are flushed from settlements and grazing lands (Juma et al., 2014; Nyaboga et al., 2019; Ojok et al., 2017). Plastics and microplastics also rise, with Nakivubo averaging ~2,140 ± 3,670 particles m^{-3} in wet months (Egessa et al., 2020). In wildlife-rich systems like Mara–Grumeti, storm pulses resuspend organic matter from hippo pools, causing nocturnal hypoxia and daytime DO swings (Subalusky et al., 2018; Dutton et al., 2022). POPs and modern pesticides likewise spike with runoff (K'Oreje et al., 2012; Fuhrimann et al., 2016).
- **Dry seasons (Jun–Aug; Dec–Feb)** Low flows and reduced dilution during dry months heighten the influence of groundwater and point-source discharges. Suspended sediments settle, improving clarity, but dissolved constituents concentrate—EC and TDS rise with evaporation and effluent inputs (e.g., Mara >2,000 µS/cm; Grumeti >3,000 µS/cm; Kisat alkalinity ~150 mg/L as $CaCO_3$) (M'Kandawire et al., 2018; Ondiek et al., 2020). pH and hardness mirror geology, from slightly acidic Kagera (pH 5.0–6.5) to alkaline Nyando (pH 7.0–8.0), while sewage inflows raise urban drain alkalinity (Nannyonjo et al., 2023; Ondoo et al., 2019). As flows slow, DO often drops below 5 mg/L in polluted reaches (e.g., Kisat 3.4–5.9 mg/L; Yala ~3.7 mg/L; Nyando 1.5–3.1 mg/L), though headwaters remain near saturation (>7–9 mg/L) (Ondiek et al., 2020; Ondiek et al., 2024; Atwebembeire et al., 2018). In semi-arid rivers like Grumeti and Mbalageti, flow cessation creates stagnant, eutrophic pools prone to hypoxia and fish

kills. Weak dilution also elevates metals and emerging pollutants such as PFAS and pharmaceuticals (Fuhrimann et al., 2016; Arinaitwe et al., 2021). Seasonal colour contrasts intensify—from wet-season brown flows to dry-season concentration of industrial hues (e.g., Yala up to 9,210 Pt-Co; Kitengure 924–1,576 Pt-Co; Kisat/ Nyashishi black-brown) (Maghanga et al., 2009; Kaggwa et al., 2024; Ondiek et al., 2020; NEMC, 2023).



Figure 5-2. *The Nyabarongo River in Rwanda. Brown colour indicates suspended sediment load. (credit: Milly Mbuliro)*

5.2.2 Classification of Rivers by Water Quality Profile

Analysis of spatial and temporal patterns presented in Section 5.1 above reveals that rivers in the Lake Victoria Basin (LVB) cluster into three broad water-quality groups shaped by land use, pollution intensity, and natural catchment characteristics. The classification highlights distinct signatures—from pristine upland streams to severely degraded urban drains—reflecting the combined influence of geology, rainfall, and human pressure.

5.2.2.1 Group 1: Urban and Industrially Impacted Rivers

These rivers drain rapidly urbanizing and industrialized areas where untreated wastewater, solid waste, and industrial effluent dominate pollution loads. They are characterized by persistent organic pollution, nutrient enrichment, microbiological contamination, and accumulation of heavy metals and plastics. Water is typically dark, odorous, and oxygen-depleted, particularly in dry months when dilution is lowest.

Key examples include:

- **Rwizi (Uganda)** – impacted by Mbarara's domestic and industrial effluent and agricultural runoff.
- **Sio (Kenya/Uganda)** – degraded by municipal waste, farming runoff, and small-scale mining.
- **Nyando (Kenya)** – affected by urban discharges, intensive agriculture, and wet-season flooding.
- **Nyashishi and Mirongo (Tanzania)** – main carriers of Mwanza city effluents, including tannery and industrial waste.
- **Kitengure (Uganda)** – polluted by artisanal gold-mining residues and tailings.
- **Kisat (Kenya)** and **Nakivubo (Uganda)** – typical urban drains conveying untreated wastewater into the lake.

Collectively, these rivers represent the basin's most degraded category, dominated by point-source pollution and severe ecological impairment.

5.2.2.2 Group 2: Sediment and Nutrient-Laden Agricultural Rivers

These rivers drain densely cultivated, erosion-prone landscapes where rainfall mobilizes soil, fertilizers, and agrochemicals into waterways. Their water quality fluctuates seasonally—relatively clear in the dry season but highly turbid and nutrient-rich during rains. Degradation stems mainly from non-point-source pollution, poor land management, and deforestation.

Representative systems include:

- **Nzoia**, **Nyando**, and **Yala (Kenya)** – principal sediment and nutrient contributors to Lake Victoria.
- **Gucha-Migori (Kenya)** – affected by hillside cultivation and agro-industrial effluents.
- **Simiyu (Tanzania)** – influenced by cropland runoff and seasonal flash floods.
- **Sondu-Miriu (Kenya)** – showing ecological decline downstream of farming zones.

These rivers illustrate the dominant role of diffuse agricultural pressures in driving eutrophication and sedimentation across the basin.

5.2.2.3 Group 3: Large National or Transboundary Systems with Mixed Pressures

The basin's major national and cross-border rivers integrate multiple environments—forest headwaters, wetland plains, agricultural lands, and urban centers—resulting in complex and spatially variable water-quality profiles. While wetlands and floodplains provide some buffering, cumulative pressures from upstream land use, livestock, and settlements still degrade water quality downstream.

Representative examples include:

- **Kagera (Burundi, Rwanda, Tanzania, Uganda)** – influenced by a mosaic of highland agriculture, wetlands, and towns.
- **Mara (Kenya, Tanzania)** – combining natural organic enrichment from wildlife areas with farming and tourism pressures.
- **Grumeti (Tanzania)** – characterized by episodic flows, wildlife influence, and localized mining impacts.
- **Katonga (Uganda)** – a wetland-dominated system that maintains relatively good quality due to strong natural filtration.

These rivers demonstrate the cumulative and transboundary nature of water-quality pressures in the LVB, where natural processes moderate but cannot fully offset widespread anthropogenic impacts.

5.2.3 Groundwater: The Basin's Hidden and Threatened Lifeline

While Lake Victoria commands regional attention as the basin's most visible water resource, the groundwater beneath it serves as the silent guarantor of water security for over 45 million people across five East African nations. This hidden resource—hosted within weathered basement aquifers—provides essential drinking water for most rural communities, contributes vital baseflow to tributary rivers, and acts as a critical buffer against climate variability (Tumwine et al., 2024a). However, this foundational water security faces mounting threats from population growth, agricultural intensification, and climate variability that demand urgent regional coordination.

5.2.3.1 Hydrogeological Foundation and Water Availability

The basin's groundwater occurs predominantly within the ancient Proterozoic Karagwe-Ankolean rock system, where deeply weathered crystalline basement formations create multi-layered aquifer systems (MacDonald et al., 2012). This geological setting provides natural climate buffering but renders aquifers highly vulnerable to surface contamination—a vulnerability that defines the basin's current water quality crisis.

The characteristic weathered profile features an upper saprolite layer of sandy-clayey material (0.2-37.3 meters thick) with low hydraulic conductivity serving primarily as storage, underlain by the critical saprock zone of highly fractured weathered rock providing main transmission pathways (Cuthbert et al., 2019). Aquifer productivity varies dramatically: Uganda shows persistently low transmissivity (median <2 m²/day), Kenya's systems range 0.1-160 m²/day, while Tanzania's high-yielding sites reach 10-1,000 m²/day, though most boreholes yield less than 1 L/s (Cuthbert et al., 2019; Bonsor et al., 2014).

Recharge depends heavily on direct rainfall infiltration, with annual rates typically 3-50 mm/year in basement areas, reaching 200 mm/year under favorable conditions. Critically, heavy rainfall events exceeding 10 mm/day prove more important than total annual precipitation for effective recharge, while deforestation can double recharge rates through reduced evapotranspiration.

Groundwater dependence varies significantly across countries but demonstrates clear strategic importance. Kenya's 619 million m³ storage potential supports national needs, though current abstraction represents only 30% of safe annual yield (IGRAC, 2024). Uganda shows highest dependence with 75% of operational water systems relying on groundwater, while 81% of the population lacks reliable water access (Water.org, 2024). Rural communities depend dominantly on shared boreholes with handpumps, contrasting with urban areas where surface water dominates supply systems.

5.2.3.2 Contamination Patterns and Health Risks

Groundwater quality in the Lake Victoria Basin is highly variable, shaped by both natural geology (geogenic sources) and increasing human pressures. While many sources meet WHO standards, several contaminants frequently exceed safe limits and pose serious health risks (Tumwine et al., 2024b).

Natural Contamination Sources Geogenic contamination creates significant risks in specific regions of the basin.

- **Salinity**: Elevated electrical conductivity (EC) and total dissolved solids (TDS) reduce water usability in some areas. In eastern Uganda, high chloride concentrations are linked to volcanic rocks, while in the Nakivale sub-catchment, medium-to-high salinity hazards threaten irrigation by increasing osmotic stress (Tumwine et al., 2024b).
- **Fluoride**: Concentrations above the WHO 1.5 mg/L guideline occur in volcanic areas of eastern Uganda and in Kenya's upper Nzoia, Nyando, Sondu, and Gucha-Migori catchments (LVBC, 2025).
- **Iron and manganese**: Common throughout the basin, often exceeding WHO aesthetic thresholds for iron (0.3 mg/L) and occasionally the health guideline for manganese (0.5 mg/L). In Uganda's Nakivale Sub-catchment, 47% of samples contained iron above limits, with some reaching 5.1 mg/L—over 15 times higher. Sources include local geology and corrosion of borehole components in acidic waters (Wanma et al., 2024).
- **Arsenic**: A critical concern in Tanzania's Lake Victoria goldfields, where ~48% of samples exceed WHO's 10 µg/L guideline, with some up to 300 µg/L (Mmbando et al., 2022). Natural arsenic mobilization, intensified by mining of sulfide-rich gold ores, is the main cause.

Human-Induced Contamination Anthropogenic sources drive the most widespread groundwater risks.

- **Nitrate contamination**: Common in shallow groundwater of agricultural and urban areas, directly linked to poor sanitation and farming practices. In Kisumu, Kenya, 75% of shallow wells exceeded WHO's 50 mg/L limit, while urban sites in Uganda show similarly high levels from latrines and markets. Some samples reached 104 mg/L—more than double the guideline (LVBC, 2025; Nyilitya et al., 2020).

- **Bacteriological contamination**: Shallow groundwater near the lake shows widespread E. coli contamination, with most sites recording high fecal coliform levels (Kinobe et al., 2015). About 20% of rural handpumps test positive, reflecting heightened health risks, especially in wet seasons when infiltration increases contamination.
- **Pollution sources**: Three main drivers dominate:
    - *Pit latrines*—the greatest threat, as leachate from unlined pits directly contaminates aquifers (Graham et al., 2013).
    - *Agriculture*—fertilizer use and manure mismanagement contribute diffuse nitrogen loads.
    - *Industry and landfills*—create localized hotspots releasing heavy metals, arsenic, and other pollutants (World Bank, 2022).

5.2.3.3 Regional Monitoring and Management Gaps

Monitoring network coverage reveals critical institutional gaps that hamper effective groundwater management. Kenya maintains 140 monitoring stations countrywide, with quarterly measurements, Uganda operates 81 stations nationally expanded from 55 in 2017, while Tanzania lacks comprehensive national coverage, maintaining only regional monitoring in four basins (IGRAC, 2024; Winrock International, 2021). Rwanda's 43 stations achieve only 0.16 stations per 100 km²—insufficient for adequate monitoring (Uwiragiye et al., 2025).

Equipment technology varies dramatically based on funding availability, ranging from advanced pressure transducers with real-time telemetry to basic manual measurements that limit data quality and frequency. Funding constraints create sustainability challenges, with primary support from the World Bank and Global Environment Facility, while national governments provide limited local funding.

The Lake Victoria Basin Commission coordinates regional activities as a specialized East African Community institution, though resource limitations affect operational capacity. Data management remains fragmented with fee-based access systems limiting information sharing between countries and researchers—a critical barrier to effective transboundary management.

5.2.3.4 Transboundary Challenges and Climate Impacts

The Kagera Aquifer System is the basin's most significant transboundary groundwater resource, spanning 59,700 km² across Tanzania (35%), Rwanda (34%), Burundi (23%), and Uganda (8%). It underlies the Kagera River Basin, the lake's largest tributary, contributing 7.5 km³ annually to Lake Victoria (FAO, 2024). The aquifer is hosted in fractured Precambrian basement rocks of the Karagwe–Ankolean system. In Nakivale, 90% of samples meet WHO drinking standards, though localized iron exceedances persist. The dominant groundwater type is calcium-sulfate, reflecting rock–water interactions (Wanma et al., 2024).

Beyond Kagera, only a few other significant transboundary systems exist. The Mt. Elgon Aquifer straddles Kenya and Uganda, but only its Kenyan portion drains into Lake Victoria. Covering Trans-Nzoia and Bungoma counties, it supports rivers like the Nzoia but is more boundary-straddling than fully basin-internal (NBI, 2024).

Ongoing Nile Basin Initiative (NBI) efforts, supported by a $5.3 million GEF project (2020–2025), target the Kagera and Mt. Elgon aquifers to strengthen governance and management. Yet, institutional gaps remain—there are no bilateral agreements, and national capacity to enforce regulations is still limited (Masese et al., 2025).

5.2.3.5 Climate Impacts and Future Pressures

Climate change adds complexity through projected warming of 1.4–2°C by 2030–2060, altering recharge and intensifying rainfall variability (Nkalubo et al., 2018). GRACE satellite data indicates groundwater accounts for 27% of terrestrial water storage variation, rising to >50% in northern basin regions (Awange et al., 2013).

Rising population (45+ million) and agricultural intensification further increase stress. Informal urban settlements with poor sanitation and expanded pesticide and fertilizer use heighten contamination risks through faster recharge pathways. Adaptive, basin-wide strategies will be essential.

5.2.3.6 Critical Management Implications

Groundwater faces a quality and security crisis, with shallow, vulnerable aquifers exposed to contamination from poor sanitation, farming, and industry. This directly undermines water security and contributes to Lake Victoria's degradation through polluted baseflows.

Addressing these threats requires proactive, integrated transboundary management, prioritizing the Kagera Aquifer as the basin's key shared resource. Priorities include:

- **Strengthening cooperation** through LVBC and NBI.
- **Establishing transboundary** groundwater agreements.
- **Harmonizing monitoring** and data-sharing.
- **Expanding safe sanitation** technologies and community-level management.

Given the strong link between groundwater and surface systems, protecting groundwater is essential for safeguarding Lake Victoria's long-term water quality and ecosystem health.

5.2.4 Synthesis

Ambient data show a coherent basin-wide pattern: rivers are the rapid vectors of pollution while groundwater is the persistent carrier. Urban–industrial tributaries exhibit acute organic loads, nutrients, pathogens, metals, and plastics; intensively farmed catchments export extreme sediments and agro-nutrients; and large transboundary systems (e.g., Kagera, Mara) integrate mixed pressures with episodic crises (turbidity surges, DO collapses). Seasonality amplifies these signals—wet-season first-flush drives peaks in sediments, nutrients, organic matter, pathogens, POPs and microplastics; dry seasons lower dilution, concentrating dissolved salts, metals, and emerging contaminants while groundwater contributions dominate flows. Groundwater—critical for rural supply and river baseflow—faces dual risks: localized geogenic hazards (fluoride, arsenic, salinity, Fe/Mn) and widespread nitrate–microbial contamination from sanitation and agriculture, directly translating into health burdens and degrading river quality via contaminated baseflows.

Effective management therefore requires: (i) **source control where loads originate**—urban wastewater and solid-waste management, industrial pretreatment, mining governance, and soil/land-management to curb erosion and agro-nutrients; (ii) **hydro-ecological buffering**—protect and restore wetlands and riparian zones that attenuate sediments, nutrients, microbes, and metals; (iii) **groundwater risk reduction**—wellhead protection, safe sanitation siting/lining, nitrate control, and targeted treatment in geogenic hotspots; and (iv) **evidence and coordination**—harmonized, open monitoring for rivers and aquifers, and strengthened transboundary arrangements for shared rivers and aquifers (notably Kagera). Without simultaneous action on these fronts, nearshore lake quality will continue to decline despite localized improvements.

5.3 Physical Limnology: The Primary Driver of Water Quality

The ambient water quality of Lake Victoria, a resource vital to the ecological and economic health of the basin, is governed by a complex interplay of physical, chemical, and biological processes. This section provides a foundational understanding of the lake's limnology by examining the primary physical engine that drives its internal functioning: the annual cycle of thermal stratification and mixing. It begins by outlining the three distinct phases of this cycle, from the establishment of a stable thermocline to the complete vertical "overturn." The discussion then demonstrates how this physical framework controls the vertical distribution and behavior of all other critical water quality parameters, including the onset of widespread seasonal anoxia, the formation of sharp chemical gradients in pH and conductivity, and the process by which nutrients are sequestered and redistributed. Understanding these powerful physical processes is essential for interpreting water quality data and assessing the profound, synergistic impacts of eutrophication and climate change on the lake's ecosystem.

5.3.1 The Physical Engine: Annual Stratification and Mixing

5.3.1.1 The Annual Cycle of Thermal Stratification and Mixing

Lake Victoria's water quality is fundamentally controlled by its physical limnology, particularly the annual cycle of thermal stratification and mixing. This cycle shapes the vertical distribution of oxygen, nutrients, and chemical gradients, and thereby regulates biological productivity, water quality, and ecosystem health. Its influence is amplified by nutrient enrichment and climate change, making it central to understanding the basin's water quality crisis.

The lake's thermal regime is driven not by strong seasonal temperature swings, as in temperate lakes, but by subtler changes in solar radiation and regional wind patterns (Nyamweya et al., 2016). With a surface area of 68,800 km², mean depth of 40 m, and a water residence time exceeding two decades, pollutants and nutrients are retained for long periods (Antillón et al., 2017).

The three-phase thermal cycle, first documented by Talling (1966), remains a robust framework for interpreting water quality. Later research, using modern monitoring and hydrodynamic models, confirms that stratification and mixing are the "master variables" controlling heat, oxygen, nutrients, and pollutants (MacIntyre et al., 2014; Sitoki et al., 2010). **Figure 5-3** shows measurements of the lake condition during a recent lake survey.



Figure 5-3. *Secchi disc used to measure lake transparency during the LVBC joint lake cruise of June-July 2025.*

- **Phase 1:** Onset of Stratification (Sep–Dec): As winds weaken and surface heating intensifies, weak stratification develops. The lake shifts from an isothermal, well-mixed state to one with growing vertical gradients. This initial layering marks the transition from a physically uniform system to one increasingly compartmentalized, setting the stage for oxygen depletion and nutrient separation (Muwanga, 2023).
- **Phase 2: Strong Stratification (Jan–May):** High solar radiation establishes a sharp thermocline at 30–60 m, dividing the lake into three layers: epilimnion (surface), metalimnion (thermocline), and hypolimnion (deep water) (**Figure 5-4**). The hypolimnion becomes isolated, and oxygen is steadily consumed by decomposing organic matter, leading to widespread anoxia. At the same time, the epilimnion remains oxygen-rich and productive, creating extreme vertical contrasts in water quality (Haldar et al., 2022). Algal photosynthesis in the epilimnion rapidly consumes dissolved CO_2 and bicarbonate, reducing carbonic acid and shifting the carbonate balance toward OH^-, which raises surface-water pH.
- **Phase 3:** The Great Overturn (Jun–Aug): Seasonal trade winds and surface cooling erode the thermocline, culminating in complete mixing. This resets the lake's vertical structure, reoxygenating deep waters and redistributing accumulated nutrients throughout the water column. The overturn is a crucial fertilization event, but it also fuels large algal blooms that further intensify eutrophication (Deirmendjian et al., 2021).

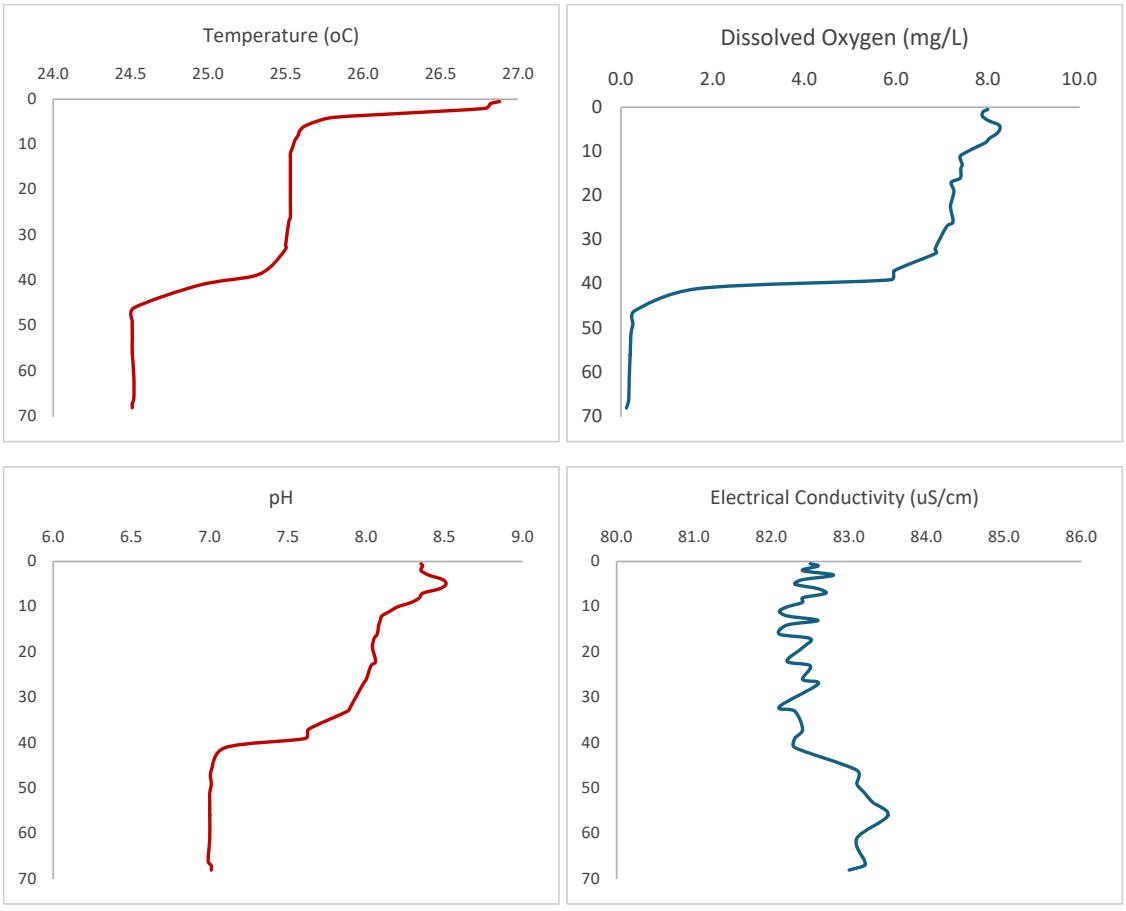


Figure 5-4. *Vertical profiles of water quality parameters at Lake Victoria offshore station TP12 in March 2003. The profiles show strong stratification with a distinct thermocline and oxycline in the metalimnion located at 37-46 m. TP12 (32.722, -1.281) lies in the Tanzanian part of the lake and has a maximum depth of 68m. (Source: LVBC, 2025).*

Stratification and mixing vary by location. Shallow littoral zones mix year-round, while sheltered eastern areas stratify more persistently. The western basin, more wind-exposed, mixes more deeply and may provide temporary refuge for fish from hypoxic stress. Such variability is critical for fisheries management and biodiversity conservation (Okely et al., 2010)

5.3.1.2 Interconnected Water Quality Dynamics: Oxygen, Chemistry, and Nutrients

The isolation of Lake Victoria's deep waters during stratification has far-reaching consequences for water quality. Once the thermocline is established, the hypolimnion is effectively sealed off from atmospheric exchange and photosynthesis, the two primary sources of oxygen replenishment (Bootsma & Hecky, 1993). Meanwhile, organic matter from surface production sinks continuously into these deep layers, where microbial decomposition consumes the remaining oxygen (Campbell et al., 2003). This imbalance leads to a steep

vertical gradient in dissolved oxygen, known as the oxycline, and eventually to complete anoxia in much of the hypolimnion. Historical records suggest that in the 1960s, anoxia was restricted to the deepest parts of the lake; today, however, it extends into shallower depths and can cover up to 40% of the lake bottom, reflecting the cumulative impact of nutrient enrichment and eutrophication (Hecky & Bugenyi, 1992; Harrington et al., 2010).

The development of this seasonal anoxia is more than just a depletion of oxygen — it triggers a cascade of chemical transformations that reshape the lake's internal environment. Oxygen acts as a redox buffer, maintaining a high oxidative potential in surface waters. Once it is exhausted in the hypolimnion, microbes turn to alternative electron acceptors such as nitrate, manganese, and iron oxides (Campbell et al., 2003). These processes create a strongly reducing environment, which alters the solubility and mobility of key elements. For example, the reduction of iron (III) to soluble iron (II) destabilizes phosphorus compounds bound in sediments, causing them to be released into the water column (Welch & Cooke, 1995). This process, known as internal phosphorus loading, ensures that even if external nutrient inputs from the catchment were reduced, large pools of "legacy phosphorus" would continue to circulate within the lake (Hecky, 1993).

Chemical gradients deepen the divide between surface and bottom waters. In the epilimnion, high photosynthetic activity removes carbon dioxide, raising pH to values as high as 9 (Gophen et al., 1993). In contrast, bacterial respiration in the hypolimnion releases CO_2, lowering pH often below 7 and increasing acidity (**Figure 5-5**). Similarly, electrical conductivity rises in the deep waters as ions from organic matter decomposition accumulate, creating a distinct chemocline (Bootsma & Hecky, 1993; Deirmendjian et al., 2021). Together with the redoxcline, these vertical chemical divides govern the distribution, form, and bioavailability of nutrients and trace metals. They also determine the conditions under which toxins, such as hydrogen sulfide, may accumulate in bottom waters (Campbell et al., 2003).

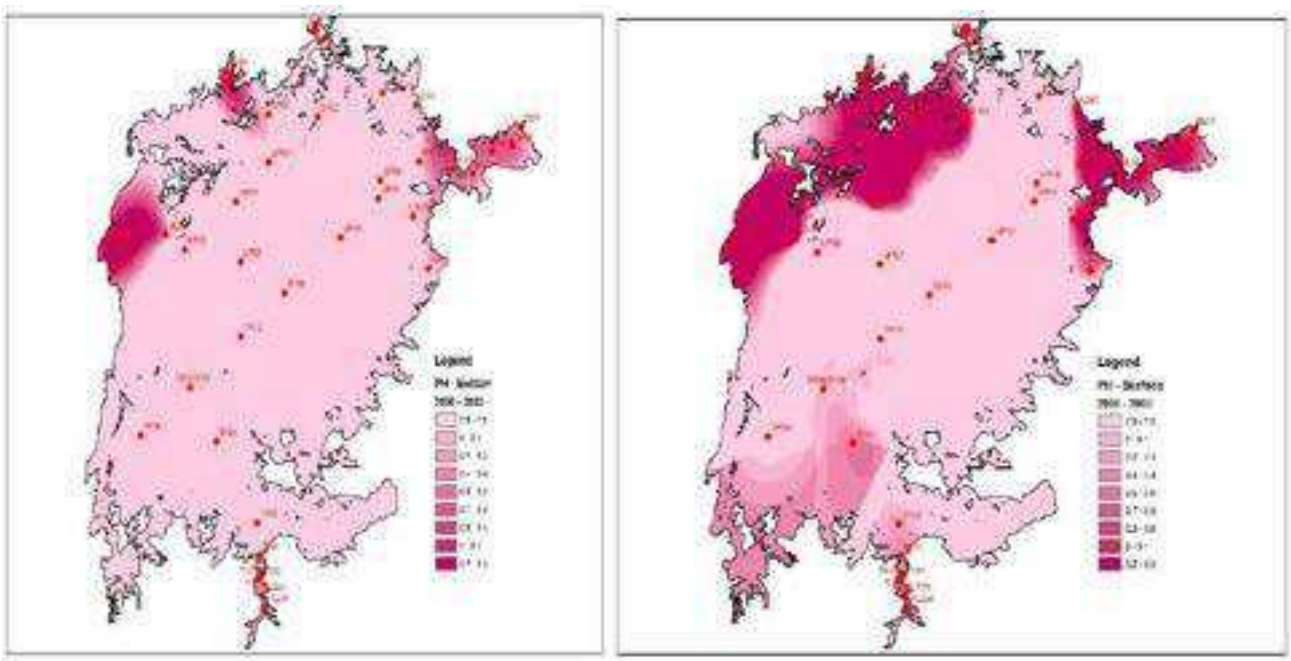


Figure 5-5. *pH in Lake Victoria's surface (left) and bottom (right) waters during strong stratification (February–April, 2000–2003). High surface pH is concentrated in the northern nearshore areas, while bottom water pH is uniformly low except in highly polluted bays and the mouth of River Kagera.* ***(Source of data: LVBC, 2025).***

The stratification cycle also dictates the timing and magnitude of nutrient fluxes that sustain the lake's high productivity. During the stratified months, the hypolimnion functions as a "nutrient trap," accumulating soluble reactive phosphorus, ammonium, and dissolved silica (Talling, 1966). Nitrogen cycling is particularly dynamic: oxygen scarcity suppresses nitrification and promotes denitrification, leading to a net loss of bioavailable nitrogen from the system. This alters nutrient ratios in ways that favor certain groups of phytoplankton over others.

The annual lake overturn and complete mixing of Lake Victoria mark a fundamental resetting of its physical and chemical dynamics. During this period—typically between June and August—the thermal and chemical gradients in the water column breakdown allowing nutrient-rich deep waters to mix with the surface, creating uniform water-quality conditions throughout the water column (see Figure 5-6). This complete mixing redistributes phosphorus, ammonium, and silica from the hypolimnion into the photic zone, acting as a massive fertilization pulse that often triggers large algal blooms. Historically, diatoms such as Aulacoseira, which thrive in turbulent, nutrient-rich conditions, dominated these blooms. However, sustained phosphorus enrichment and silica depletion have shifted the system toward nitrogen-fixing cyanobacteria (Hecky et al., 2010; Nyamweya et al., 2016).

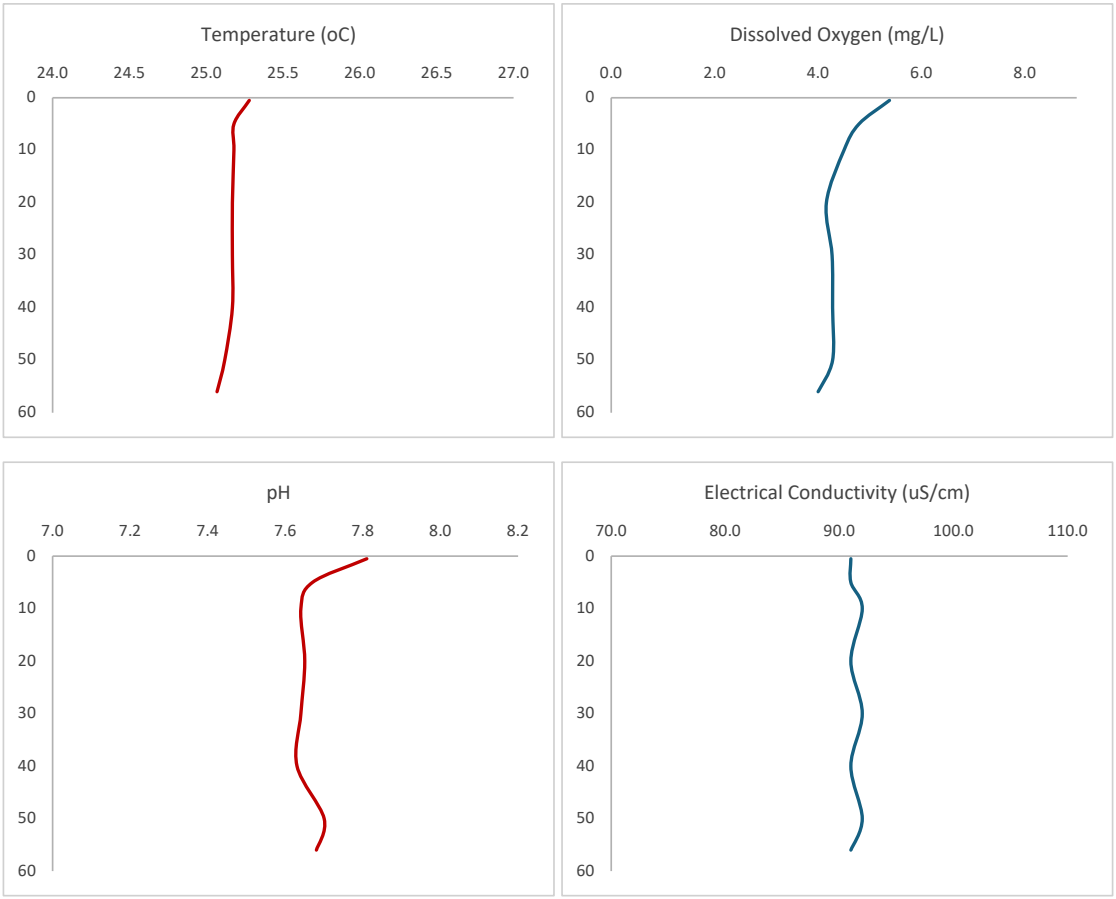


Figure 5-6. *Vertical profiles of water quality parameters at Lake Victoria offshore station UP04 in July 2025. Stratification has broken down, and the lake is fully vertically mixed. UP04 (32.932, -0.322) lies in the Ugandan part of the lake and has a maximum depth of 56 m. (Source: LVBC, 2025).*

Over decades, this interplay of stratification, oxygen depletion, chemical gradients, and nutrient cycling has driven a profound ecological regime shift in Lake Victoria. Offshore chlorophyll-a concentrations, a measure of algal biomass, rose nearly ten-fold between the 1960s and the 1990s, while water clarity (Secchi depth) declined from more than 8 m to less than 2.5 m (Hu & Campbell, 2014). These changes destabilized the food web, reducing larger zooplankton grazers and altering fish productivity (Awange et al., 2008; Jeppesen et al., 2003). The result is a tightly coupled system in which physical isolation, oxygen dynamics, and chemical transformations reinforce one another, locking the lake into a self-perpetuating cycle of eutrophication that is difficult to reverse.

5.3.2 Synthesis and Broader Implications: Eutrophication, Climate Change, and the Future of Lake Victoria's Water Quality

Thermal stratification is the central physical process that governs water quality dynamics in Lake Victoria, but its effects are no longer operating in isolation. Instead, they are being amplified by two reinforcing anthropogenic pressures: nutrient enrichment from the catchment and global climate change. Together, these forces are driving the lake into a state of ecological instability that threatens its biodiversity, fisheries, and the livelihoods of millions of people across the basin (World Bank, 2024a, 2024b).

Eutrophication has already transformed the lake into a nutrient-saturated system. Excessive external loading of phosphorus and nitrogen from agriculture, sewage, and industrial effluents has fueled explosive phytoplankton growth. The decomposition of this algal biomass consumes oxygen in the deep layers, expanding the anoxic "dead zones" that now occupy vast areas of the lake bottom (Hecky, 1993; Deirmendjian et al., 2021) (**Figure 5-7**). These anoxic conditions also accelerate the release of legacy phosphorus from sediments, creating a powerful positive feedback loop in which eutrophication and anoxia reinforce each other (Welch & Cooke, 1995). The result is a system that recycles its own nutrients and remains locked in a degraded state, even if external nutrient inputs were to be reduced.

Climate change is making this situation worse. Rising global temperatures increase the thermal contrast between surface and deep waters, leading to stronger and more persistent stratification (Johnson et al., 2009; Jane et al., 2021). Longer stratification periods prolong hypolimnetic isolation, causing oxygen depletion to extend in both duration and spatial extent. As a consequence, the release of internal phosphorus intensifies, further accelerating eutrophication. Climate warming therefore acts as an invisible amplifier, locking Lake Victoria into a trajectory of deeper anoxia, more frequent algal blooms, and declining water quality.

"Eutrophication has already transformed the lake into a nutrient-saturated system. Excessive external loading of phosphorus and nitrogen from agriculture, sewage, and industrial effluents has fueled explosive phytoplankton growth."

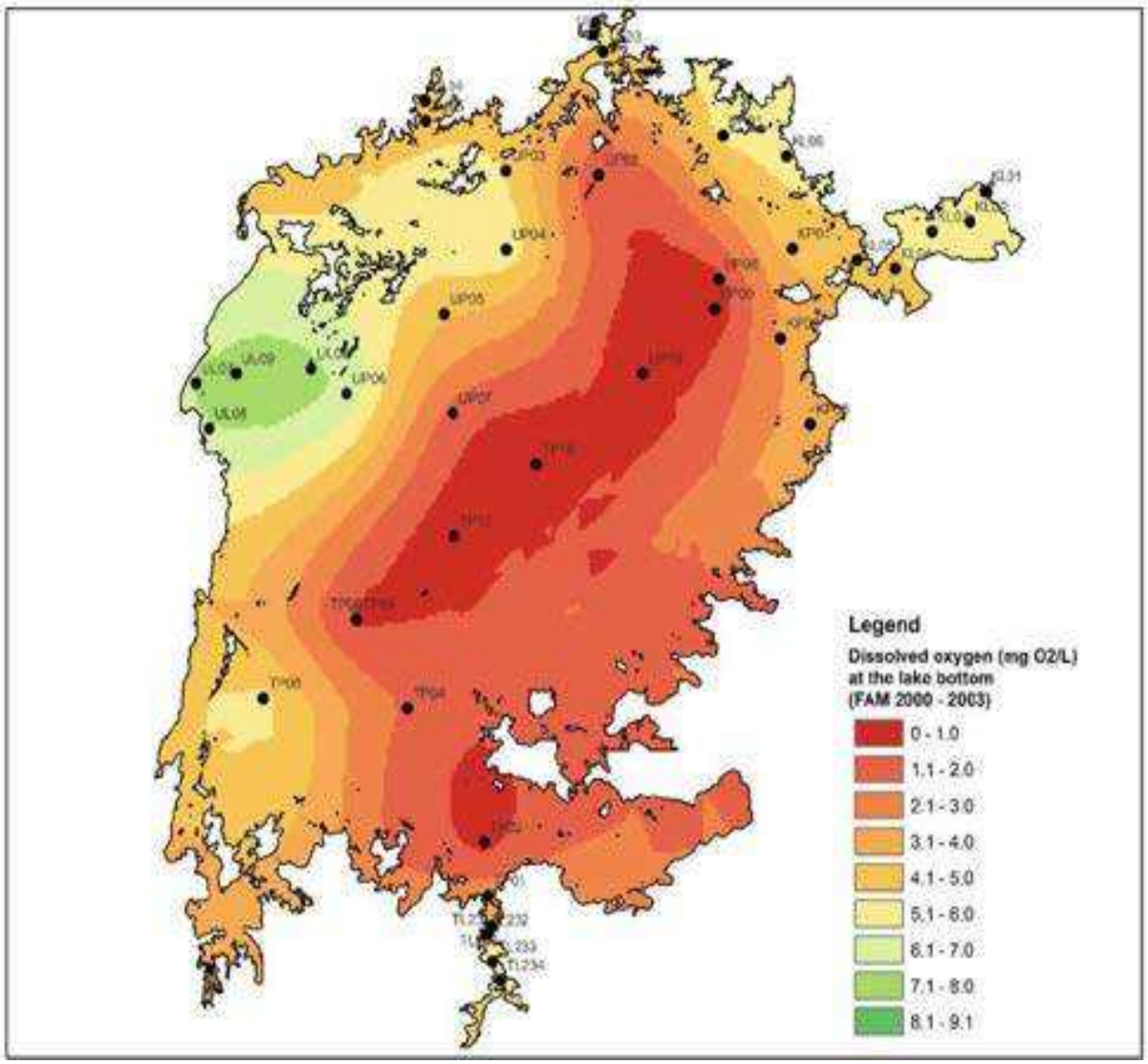


Figure 5-7. *Dissolved oxygen levels in the bottom 2 meters of Lake Victoria during strong stratification (February–April, 2000–2003), showing severe hypolimnetic hypoxia in the central and southeastern parts of the lake. (Source: LVBC, 2025) (Source of data: LVBC, 2025*

The ecological impacts of these shifts are profound. The expansion of anoxic zones compresses the habitable space for fish, forcing them into the warmer, shallower epilimnion. This "habitat squeeze" increases interspecific competition, elevates vulnerability to fishing pressure, and undermines the resilience of economically vital species such as Nile perch. At the same time, nutrient imbalances and silica depletion have shifted the phytoplankton community from nutritious diatoms to nitrogen-fixing cyanobacteria, which are less edible to zooplankton and can release toxins into the water (Paerl et al., 2011; Deirmendjian et al., 2021). This transformation destabilizes the food web, lowering fish productivity and threatening the lake's role as a protein source for millions.

These ecological processes also translate into human risks. The proliferation of cyanobacterial blooms not only reduces fish yields but also compromises water supplies by producing

cyanotoxins, which can pose severe health risks to communities that rely directly on untreated lake water. At the same time, declining water quality exacerbates the prevalence of waterborne diseases such as cholera and typhoid, especially during floods when sewage contamination peaks (Okungu et al., 2005). Thus, the degradation of water quality is not just an ecological issue but also a public health and socio-economic crisis.

In sum, Lake Victoria's limnological engine — its annual cycle of stratification and mixing — has been profoundly altered by human pressures. The synergistic interaction of nutrient enrichment and climate change has deepened the eutrophication-anoxia feedback loop and reduced the lake's ecological resilience. Breaking this cycle will require a dual strategy: first, reducing external nutrient and pollutant inputs through catchment management, wastewater treatment, and agricultural best practices; and second, integrating climate adaptation measures into regional water governance. Without decisive action, the trajectory of degradation will continue, eroding both the ecological integrity of the lake and the socio-economic well-being of the basin's population.

5.4 Spatial Patterns and Temporal Fluctuations in Lake Water Quality

Understanding the spatial and temporal dynamics of water quality is critical for assessing the ecological health of Lake Victoria. Over recent decades the lake has entered a persistently eutrophic state, with chronic nutrient enrichment, deoxygenation, and recurrent algal blooms reshaping its ecosystems. These changes are neither uniform across the basin nor constant over time, creating complex patterns that require systematic investigation to understand their underlying drivers and ecological implications.

This section synthesizes insights from complementary monitoring approaches—satellite remote sensing and field measurements—to reveal the full scope of Lake Victoria's water quality dynamics. By combining lake-wide mapping capabilities with detailed local observations, we can identify where and when conditions are most severe, understand the processes driving these patterns, and identify the most promising pathways for restoration.

5.4.1 Satellite Mapping: Revealing Lake-Wide Pollution Patterns

5.4.1.1 The Challenge of Monitoring a Vast System

Lake Victoria's vast area (≈68,800 km²) has historically posed significant challenges for comprehensive water quality assessment. Traditional boat-based sampling (**Figure 5-8**), while locally precise, is costly and logistically difficult to deploy at sufficient density across the entire lake basin. This limitation left critical knowledge gaps about pollution distribution and temporal trends across the lake.

The advent of satellite remote sensing has transformed water-quality monitoring in Lake Victoria. Modern Earth Observation platforms such as ***Sentinel-2/3*** and ***Landsat*** provide frequent, synoptic coverage of the entire lake surface, enabling the derivation of key water-quality proxies—such as chlorophyll-a, turbidity, and suspended solids—from multispectral imagery. When combined with ground-truth calibration, these systems offer cost-effective, large-scale, and continuous monitoring capabilities that were previously unattainable (Awange et al., 2019; Jeppesen et al., 2003). However, satellite-based monitoring remains

constrained by persistent cloud cover and atmospheric interference, which limit data quality and temporal continuity; by sensor resolutions often too coarse to capture nearshore gradients; and by the inherent restriction of optical methods to surface conditions, leaving subsurface dynamics unobserved. Reliable calibration further depends on well-distributed in-situ datasets, which remain scarce across much of the basin (International Ocean Colour Coordinating Group [IOCCG], 2020).

5.4.1.2 The "pollution halo" phenomenon

Analysis of multi-decadal Landsat imagery (2005-2023) has revealed a troubling and persistent spatial pattern. Researchers computed a composite Water Quality Index (WQI) using spectral indices for chlorophyll-a and turbidity, classifying lake regions from "Good" to "Very Unhealthy" (Onyango et al., 2024). The results show severe degradation concentrated along the lake's perimeter, creating what researchers term a "pollution halo" around the littoral zone (**Figure 5-9**).



Figure 5-8. *Staff of the Water Quality Management Department in Uganda carrying out water sampling in Lake Victoria. It is very costly to have comprehensive coverage of the lake through boat-based sampling (WQMD, Uganda).*

This belt of degraded water encompasses semi-enclosed bays receiving heavy loads from major cities—Winam Gulf near Kisumu, Murchison Bay near Kampala, and Mwanza Gulf near Mwanza—as well as areas adjacent to major river inputs like the Kagera and Nyando. Meanwhile, offshore waters remain comparatively cleaner due to dilution effects and distance from direct pollution sources. The World Bank's assessment confirms this stark contrast: virtually the entire shoreline now exhibits hyper-eutrophic conditions, with no nearshore sites achieving "good" status (World Bank, 2018).

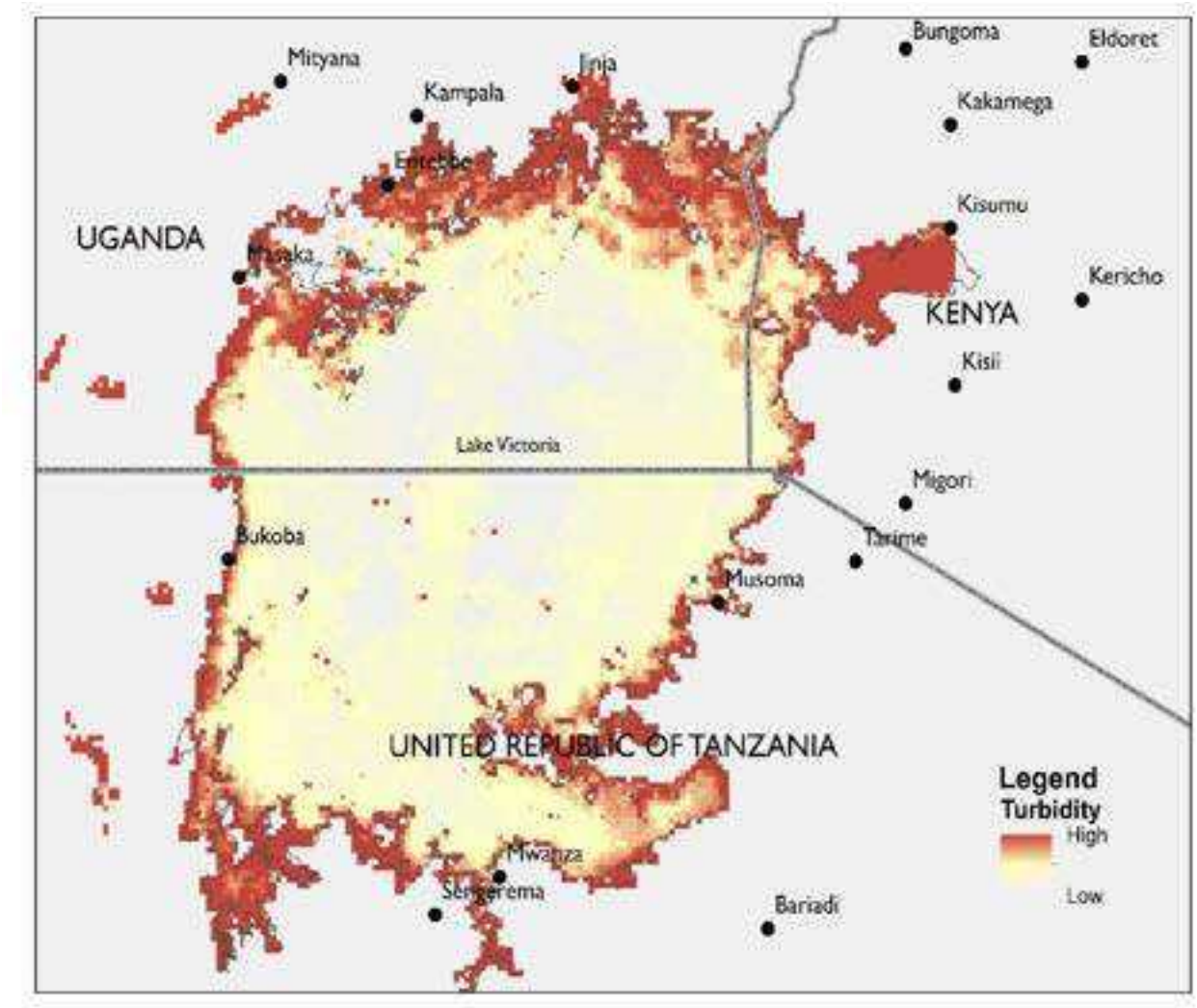


Figure 5-9. *Turbidity levels on 21 October 2024 showing the ring of poor water quality all-round the lake rim. (The Copernicus Global Land Service).*

5.4.1.3 Evidence of Long-Term Deterioration

Beyond mapping current conditions, the satellite time series reveals alarming trends in the lake's trajectory over the past two decades. The long-term analysis shows that Lake Victoria's water quality has steadily declined, with the deterioration appearing to accelerate in recent years. Areas that maintained relatively good water quality in the 2000s had largely degraded by the 2010s, suggesting cumulative impacts from sustained pollution loading.

A particularly striking finding emerged around 2013, when lake-wide WQI values dropped sharply across multiple monitoring locations. This synchronized deterioration indicates the lake system may have crossed a critical ecological threshold, transitioning into a new, more uniformly degraded stable state. By 2023, over 70% of monitored locations were classified as "Very Unhealthy," with virtually no areas remaining in the "Good" category (Onyango et al., 2024).

This trajectory suggests that decades of cumulative nutrient and pollutant loading, compounded by accelerating land-use change in the catchment, may have pushed the lake's ecosystem beyond its resilience capacity. Such hypereutrophic conditions, once entrenched, are exceedingly difficult to reverse, implying the lake could remain locked in this degraded state without substantial intervention. The comparative values presented in **Table 5-2** further illustrate this progressive decline, highlighting the widening gap between the lake's cleaner offshore waters and its increasingly degraded nearshore zones.

5.4.1.4 Seasonal Dynamics from Space

High-resolution sensors (Sentinel-2) combined with cloud-computing platforms (Google Earth Engine) reveal seasonal patterns tied to the region's bimodal rainfall (March-May and October-December wet seasons). During rainy seasons, heavy runoff delivers surges of nutrients and sediments from the watershed, which manifest in satellite imagery as expanding turbidity plumes at the mouths of major rivers like the Kagera, Mara, Nzoia, and Nyando (**Figure 5-10**). These sediment-laden plumes can spread for many kilometers into the lake, dramatically reducing water transparency while carrying phosphorus-rich silt that fuels subsequent algal growth. These seasonal inputs are compounded by atmospheric deposition, as dust and ash from agriculture and biomass burning that accumulate during dry periods are flushed into the lake by the first rains (Tamatamah et al., 2012).



Figure 5-10. *Satellite images of the mouth of the Kagera River (left) in April 2011, and Nzoia River (right) in March 2019. The images show sediment plumes entering Lake Victoria. (Google Earth).*

Table 5-2. This table presents data that compares long-term water quality trends in Lake Victoria across four periods: the 1980s–90s, 2000–2003, and 2020–2025. The most recent column combines published studies (2020–2024) with Partner States' monitoring data, which were collected during the dry season (June-July) of 2025. The integrated values confirm the strong nearshore–offshore gradient: clearer, less nutrient-rich waters offshore versus turbid, nutrient-enriched and sometimes hypoxic conditions in bays and gulfs.

Category	Parameter	Offshore Areas			Nearshore Areas		
		1980s–90s (Wet; Dry)	2000–2003 (Wet)	2020–2025 (Wet; Dry)	1980s–90s (Wet; Dry)	2000–2003 (Wet)	2020–2025 (Wet; Dry)
Clarity	Transparency (Secchi, m)	~2–3 (Njiru et al., 2020)	–	3–4; 1.2–5.5 in 2025 wet season (Njiru et al., 2020; LVBC, 2025)	~1–2 (Sitoki et al., 2010)	–	0.5–2; 0.7–3.2 in 2025 wet season (Nalwanga et al., 2024; LVBC, 2025)
	Turbidity (NTU)	~1–10 (Orina et al., 2020)	3.17–21.83 (LVBC, 2025)	<10 offshore; 2.6–10.5 in 2025 wet season (Orina et al., 2020; Juma et al., 2023; LVBC, 2025)	10–30; spikes >30 (Sitoki et al., 2010)	12.05–62.2 (LVBC, 2025)	20–30 typical; up to 60+ NTU, 2.8–10.5 in 2025 wet season (Orina et al., 2020; Nalwanga et al., 2024; LVBC, 2025)
	Euphotic Depth (m)	–	–	2.8–12.7 in 2025 wet season (LVBC, 2025)	–	–	Often <3 in bays; 1.6–7.4 in 2025 wet season (Nalwanga et al., 2024; LVBC, 2025)
Algal Biomass	Chlorophyll-a (µg/L)	~14 avg. (Hecky et al., 2010)	–	3–8 offshore, blooms episodic (Nalwanga et al., 2024); <1.5-35 (LVBC, 2025).	~20–60 during blooms (Haande et al., 2011)	–	20–60 typical; up to 70–80 in bays (Nalwanga et al., 2024); LVBC, 2025).
Oxygen Regime	Dissolved Oxygen (mg/L)	~7–8, daytime supersaturation (Sitoki et al., 2010)	5.17–8.69 (LVBC, 2025)	6–8 offshore; 3.6–5.8 in 2025 wet season (Deirmendjian et al., 2021; LVBC, 2025)	~5–10, diurnal swings (Haande et al., 2011)	5.34–9.15 (LVBC, 2025)	2–6 typical; frequent hypoxia; 4.2–5.8 in 2025 wet season (Nalwanga et al., 2024; LVBC, 2025)

Category	Parameter	Offshore Areas		Nearshore Areas			
		1980s–90s (Wet; Dry)	2000–2003 (Wet)	2020–2025 (Wet; Dry)	1980s–90s (Wet; Dry)	2000–2003 (Wet)	2020–2025 (Wet; Dry)
Nutrients	Nitrate, NO_3–N (mg/L)	~0.01–0.03 (Hecky et al., 2010)	0.01–0.08 (LVBC, 2025)	0.1–0.4 offshore (Njiru et al., 2020; Nalwanga et al., 2024; LVBC, 2025)	~0.02 (Hecky et al., 2010)	0.01–0.18 (LVBC, 2025)	0.3–0.8 in bays; >1 near inflows (Nalwanga et al., 2024); LVBC, 2025)
	Total Nitrogen (mg/L)	~0.5–0.7 (Hecky et al., 2010)	0.11–0.92 (LVBC, 2025)	~0.5–0.8 offshore (Njiru et al., 2020; Nalwanga et al., 2024); LVBC, 2025)	~0.5–1.0 (Sitoki et al., 2010)	0.26–1.84 (LVBC, 2025)	2–5 typical; up to 10+ in bays (Nalwanga et al., 2024); LVBC, 2025)
	Soluble Reactive Phosphorus (mg/L)	~0.01–0.05 (Hecky et al., 2010)	0.03–0.05 (LVBC, 2025)	0.02–0.05 offshore (Njiru et al., 2020; Nalwanga et al., 2024)	~0.03–0.05 (Sitoki et al., 2010)	0.01–0.10 (LVBC, 2025)	0.05–0.15 in bays; elevated near Kampala/Kisumu (Nalwanga et al., 2024)
	Total Phosphorus (mg/L)	~0.05 (Hecky et al., 2010)	0.06–0.49 (LVBC, 2025)	0.05–0.07 offshore (Njiru et al., 2020; Nalwanga et al., 2024)	~0.05 (Sitoki et al., 2010)	0.04–0.54 (LVBC, 2025)	0.1–0.2 typical; >0.3 in bays (Nalwanga et al., 2024)
Silica Dynamics	Dissolved Silica (mg/L)	~0.6–1.5; near zero wet season (Deirmendjian et al., 2021)	0.15–1.78 (LVBC, 2025)	~1–2 offshore (Deirmendjian et al., 2021; Nalwanga et al., 2024) 1.2-2.4 (LVBC, 2025)	~0.6 (1980s)	0.01–3.62 (LVBC, 2025)	2–3 typical; up to 10–15 near inflows (Nalwanga et al., 2024); 0.004-4.6 (LVBC, 2025)

As conditions stabilize after the rains, satellite imagery from the dry season shows clear river water entering the lake—such as the distinct, sediment-free flow of the Mara River illustrated in **Figure 5-11**—while phytoplankton biomass spikes in the lake's shallow, poorly flushed bays. Satellite-derived chlorophyll indices consistently show annual peaks in bays like Winam Gulf and Murchison Bay during post-rainy periods, when the ecosystem rapidly exploits accumulated nutrients once sunlight returns (Onyango et al., 2024).



Figure 5-11. *Satellite image of the mouth of the Mara River in December 2018 showing a clear, sediment-free stream entering the lake at this time of the year. The extensive lower Mara wetland system acts as a natural sediment trap, filtering out silt and contaminants derived from upstream agricultural and mining activities, wildlife movements, and bank erosion. (Google Earth).*

This creates a recurring seasonal pattern: water quality deteriorates as turbidity and nutrients peak with runoff, followed by explosive algal blooms as waters clear and stratify in the subsequent dry period. Each rainy season essentially initiates a predictable boom-and-bust cycle that has become a defining feature of Lake Victoria's water quality regime (Onyango et al., 2024).

5.4.2 Field Monitoring: Understanding Process and Variation

5.4.2.1 Ground-Truth Validation of Spatial Gradients

While satellite observations provide the broad spatial context, detailed field measurements are essential for understanding the underlying biogeochemical processes and validating remote sensing interpretations. Extensive in-situ monitoring campaigns across Lake Victoria have been conducted to measure physical, chemical, and biological parameters at nearshore and offshore locations.

Field measurements confirm and quantify the extreme spatial heterogeneity suggested by satellite data. The contrast between littoral and pelagic zones is particularly striking for key water quality indicators:

- **Turbidity:** Turbidity measurements reveal the dramatic difference in water clarity between zones. In Tanzanian nearshore sites, recorded turbidity ranged from approximately 1 NTU up to 347 NTU (mean ~6 NTU), with similarly high values of 125 NTU recorded near Kisumu in Winam Gulf during sediment influx events. In contrast, offshore turbidity typically remained between 1 and 16 NTU (mean ~2 NTU), representing an order of magnitude difference that reflects both direct sediment inputs and resuspension in shallow waters.
- **Chlorophyll-a**: Similarly, chlorophyll-a concentrations (a plant photosynthetic pigment used as a proxy for algal biomass) show a consistent spatial gradient reflecting nutrient availability and algal productivity. Nearshore waters typically support roughly double the algal biomass of offshore waters—Tanzanian littoral zones averaged approximately 12 µg/L chlorophyll-a compared to 6 µg/L offshore (Mjemah et al., 2021). In the most nutrient-rich bays, chlorophyll levels periodically reach tens of µg/L, far exceeding offshore concentrations. In the joint lake cruise of the Partners States carried out in June-July 2025, average chlorophyll-a levels were 4.5 ug/L in offshore areas, and 15.4 ug/L in nearshore areas (LVBC, 2025) (**Figure 5-12**).

The underlying driver of these biological patterns becomes clear when examining nutrient concentrations. Measurements at polluted shoreline sites reveal extreme enrichment—for example, ammonium-nitrogen levels of 1.278 mg/L at Dunga Beach (Kisumu), whereas offshore ammonia typically occurs at an order of magnitude lower concentration (Ondiba et al., 2020) (**Figure 5-13**). This high nutrient availability in nearshore waters directly drives the intense algal production that underpins the lake's eutrophication gradient.

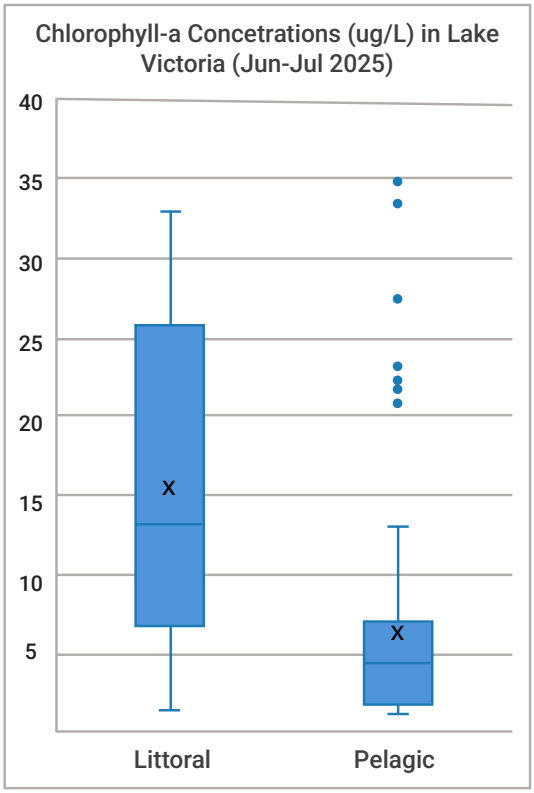


Figure 5-12. *Chlorophyll-a concentrations in Lake Victoria in June-July 2025. Nearshore areas have more plant pigment than offshore areas. (Source: LVBC, 2025)*

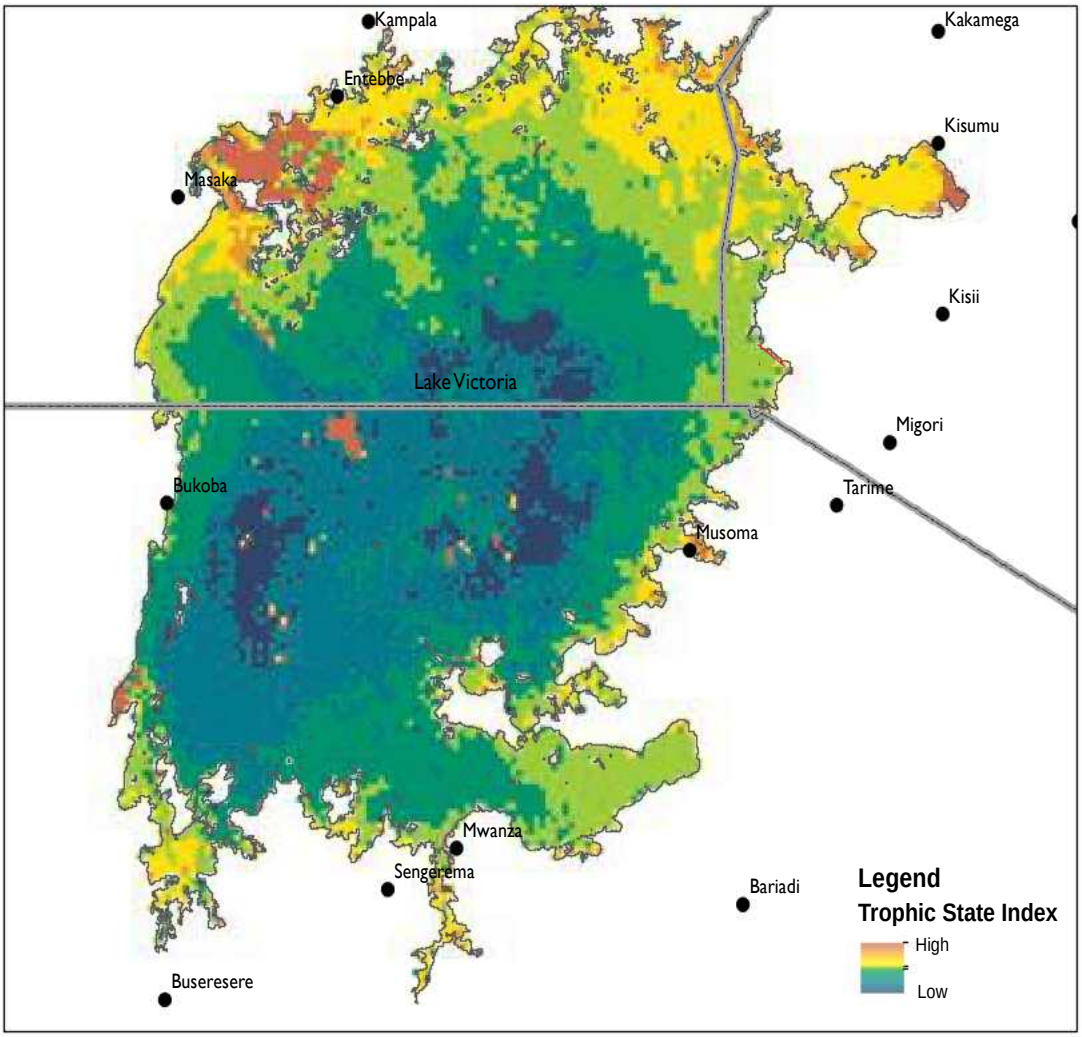


Figure 5-13. *Remote sensing image showing high trophic status in northern nearshore areas and relatively lower trophic status in offshore waters of Lake Victoria. These patterns have been confirmed by in-situ measurements.*

5.4.2.2 Intensive Study of Eutrophication Hotspots

Researchers have conducted detailed investigations in the semi-enclosed gulfs and bays—including Winam Gulf in Kenya, Mwanza and Speke Gulfs in Tanzania, and Murchison Bay in Uganda—that represent Lake Victoria's most critical eutrophication hotspots. These investigations reveal that gulfs and bays function as effective nutrient traps due to their unique hydrodynamic characteristics. Limited water exchange with the main lake prevents rapid dilution of incoming pollutants from nearby cities and rivers, allowing nutrients to accumulate and creating distinct biogeochemical conditions (Musinguzi et al., 2024).

Water quality measurements in these zones consistently show elevated phosphorus and nitrogen levels that drive chronic algal production (**Figure 5-14**). For example, soluble phosphate concentrations in the polluted Mwanza and Speke Gulfs have been reported in the 55-69

µg/L range, with total phosphorus around 0.1 mg/L—levels that firmly place these areas in the hypereutrophic category (Musinguzi et al., 2024).

A critical finding from these detailed studies concerns the lake's overall nutrient stoichiometry. Analysis reveals that Lake Victoria's nitrogen-to-phosphorus (N:P) ratio averages around 7-8:1 by mass, indicating a relative deficit of nitrogen compared to phosphorus. This imbalance creates conditions that strongly favor cyanobacteria, particularly nitrogen-fixing species like ***Microcystis aeruginosa*** and ***Dolichospermum flosaquae***. The result is a self-reinforcing cycle: phosphorus enrichment promotes cyanobacterial blooms, whose decay consumes oxygen and promotes denitrification, further maintaining low N:P ratios that perpetuate cyanobacterial dominance.

5.4.2.3 Seasonal Field Monitoring: Loading and Bloom Phases

Regular field monitoring programs have documented the mechanisms behind satellite-observed seasonal patterns. During wet seasons, nutrient concentrations surge dramatically—in 2020 Winam Gulf monitoring, total nitrogen jumped from ~0.3 mg/L to ~2.4 mg/L (eight-fold increase), while total phosphorus rose from ~0.03 to ~0.08 mg/L during the April rainy period.

Paradoxically, these periods of peak nutrient availability often coincide with suppressed algal growth due to high turbidity and mixing that limit light penetration—creating a "loading phase" where nutrients accumulate while biological productivity remains constrained. The transition to a "bloom phase" occurs as rains subside: sediments settle, water clarity improves, and stratification re-establishes. In the same 2020 study, chlorophyll-a didn't peak (~40 µg/L) until July, weeks after maximum nutrient loading, with phytoplankton counts climbing from ~600 to ~2,800 individuals per mL (Onyango et al., 2024).

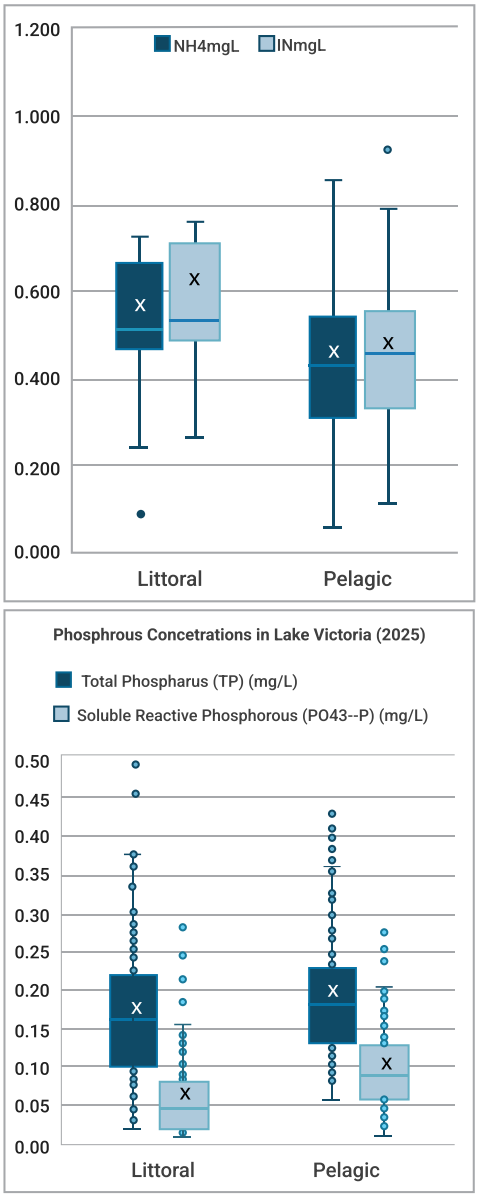


Figure 5-14. *[Left] Nitrogen concentrations (Feb–Apr 2000–2003) and; [Right] phosphorous concentrations (June-July, 2025) in littoral (nearshore) and pelagic (offshore) zones of Lake Victoria. Higher values of nitrogen in nearshore areas in the wet season reflect greater terrestrial inputs from catchment runoff and lower dilution. Higher phosphorous concentrations in offshore areas reflect the legacy of nutrient accumulation in deeper sediments and internal loading processes that become expressed once mixing redistributes bottom-water nutrients throughout the water column. (data source: LVBC, 2025).*

5.4.2.4 Extreme Oxygen Dynamics

Field monitoring has revealed severe ecological consequences of high algal biomass through effects on dissolved oxygen. Continuous monitoring during bloom periods documents extreme diurnal fluctuations: afternoon photosynthetic supersaturation (150-200% saturation) followed by pre-dawn hypoxic conditions (<2 mg/L) as respiration and decomposition consume available oxygen. These swings create direct ecological stress, with fish kills observed when overnight oxygen depletion becomes severe (Haande et al., 2011).

5.4.3 Climate Interactions and System Vulnerability

5.4.3.1 Wind Mixing as a Controlling Factor

A crucial insight from long-term monitoring concerns the role of physical forcing in mediating the lake's response to nutrient loading. Despite continued high nutrient inputs, recent algal blooms haven't reached the extraordinary intensities of the 1990s crisis—nearshore chlorophyll-a averaged ~10 µg/L in 2018-2019 versus ~50-70 µg/L during the 1990s peak (Stenuite et al., 2021).

Research attributes this apparent paradox to stronger wind regimes over recent decades, which have increased vertical mixing and frequently stirred phytoplankton below the photic zone, limiting growth despite abundant nutrients (van Oosterhout et al., 2018). This wind-mixed state has suppressed the full expression of the lake's eutrophic potential, providing a form of physical "reprieve" from the worst conditions. They also cased unique water quality spatial patterns as shown in **Figure 5-15 below.**

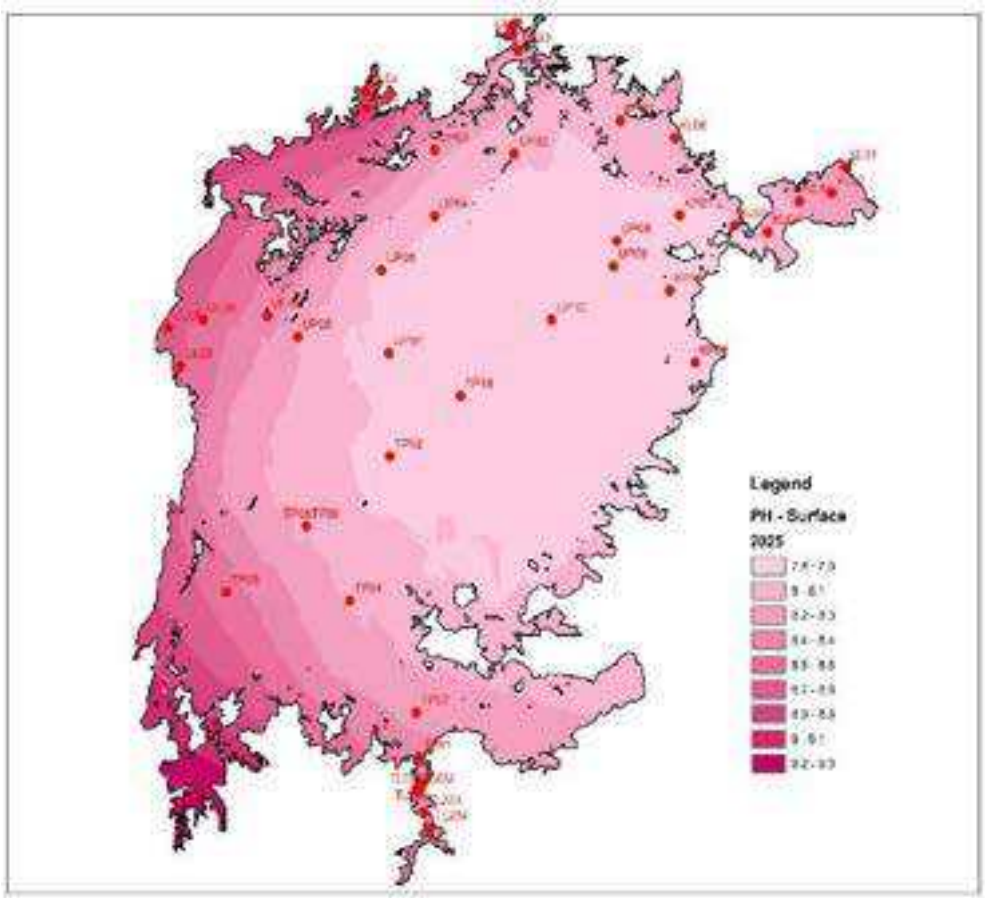


Figure 5-15. *Spatial pattern of surface water pH (0.5 m) across Lake Victoria during complete mixing (June-July 2025), showing elevated values in the western and southern parts of the lake. Strong seasonal winds may have caused an accumulation of algal biomass in the western and southern parts of the lake producing elevated photosynthetic activity and the high pH in these parts. (data source: LVBC, 2025).*

5.4.3.2 Climate Vulnerability and Future Risks

However, this reprieve leaves the ecosystem precariously positioned for rapid deterioration should mixing conditions change. The lake's high nutrient content means it remains primed for severe eutrophication under different physical conditions. Climate oscillations like El Niño demonstrate this vulnerability—the warmer, calmer conditions reduce wind speeds and allow stronger stratification, enabling phytoplankton to remain in surface waters and triggering explosive bloom development. Historical records confirm this pattern: strong El Niño years (1997-1998, late 2000s) coincided with some of Lake Victoria's most severe algal bloom and hypoxia episodes (Sitoki et al., 2010; Verschuren et al., 2002).

5.4.3.3 Shifting Limiting factors in Lake Ecology

The ecological evolution of Lake Victoria's eutrophication reflects a succession of shifting limiting factors rather than a single controlling element.

During the pre-1960s, the lake was primarily phosphorus-limited, supporting a balanced phytoplankton community dominated by diatoms. Through the 1960s–1980s, rising phosphorus inputs from catchment development and expanding urban centres fuelled massive diatom blooms that progressively depleted dissolved silica (DSi)—a key element for diatom frustule formation. As DSi concentrations fell to near-zero levels in many areas, diatoms collapsed and were replaced by non-siliceous cyanobacteria, marking the onset of the modern eutrophic state (LVEMP, 2002; Verschuren et al., 2002).

By the 1990s–2000s, intensifying anoxia and sediment denitrification further altered nutrient stoichiometry, shifting the system toward nitrogen limitation and favouring nitrogen-fixing cyanobacteria such as ***Microcystis*** and ***Dolichospermum***. In recent decades, however, despite persistently high nutrient concentrations, overall productivity has become increasingly constrained by physical controls—particularly deep wind-induced mixing that disperses phytoplankton below the photic zone, reducing light availability and suppressing bloom intensity (Stenuite et al., 2021; van Oosterhout et al., 2018).

This sequence demonstrates that Lake Victoria's trophic dynamics have no single, static limiting factor; rather, ecological controls evolve as new pressures and feedbacks emerge. Recognising these transitions is essential for management: the lake's current state—nutrient-saturated yet physically moderated—could shift abruptly if mixing regimes change (see **Section 5.4.3.2**) or if climatic calm periods prevail. The subsequent discussion (**Section 5.4.4**) further explores how these evolving constraints underpin the divergent trajectories observed between offshore recovery and nearshore decline.

5.4.4 Divergent Trajectories: Offshore Recovery versus Nearshore Decline

5.4.4.1 Offshore Waters: Signs of Partial Recovery

The open lake reveals a story of modest recovery since the 1990s crisis. Transparency has improved, with Secchi depth rising from <2 m to 3-4 m, while chlorophyll-a concentrations have fallen from ~14 µg/L to ~2.8-3.0 µg/L (Njiru et al., 2020; Nalumenya et al., 2024). Light attenuation coefficients have decreased, indicating deeper penetration. Dissolved silica has rebounded to 2.0-2.5 mg/L by 2018, suggesting modest diatom recovery after near-disappearance in the 1990s (Deirmendjian et al., 2021).

These improvements reflect the benefits of enhanced mixing, which has dispersed algae more evenly and prevented excessive bloom formation. However, offshore waters remain nutrient-rich, with high total nitrogen and phosphorus maintained by external loading and internal recycling (Hecky et al., 2010). The system remains "primed" for eutrophication, with current stability dependent on continued physical mixing.

5.4.4.2 Nearshore Waters: Persistent Deterioration

Nearshore zones, particularly urban bays, show contrasting trends of persistent or worsening degradation (Figure 5-16 and Figure 5-17)). Murchison Bay near Kampala exemplifies this decline: transparency remains very poor (1-2 m), turbidity often exceeds 100 NTU with extreme values up to ~500 NTU, and nutrient enrichment is severe (Orina et al., 2020). Soluble reactive phosphorus has risen from ~0.05 mg/L in the 1990s to >1.4 mg/L, while current total nitrogen reaches 5-30 mg/L—ten times higher than offshore values (Kabenge et al., 2016).

This enrichment sustains dense cyanobacterial populations averaging 25-30 µg/L chlorophyll-a, often forming visible surface scums. Extreme daily oxygen swings create ecological stress—daytime supersaturation (~150%) followed by predawn hypoxia (2-4 mg/L), causing periodic fish kills. Human health risks are also acute: cyanotoxin episodes and fecal contamination have forced periodic shutdowns of water treatment plants, with links to cholera and diarrheal disease outbreaks (Sitoki et al., 2010; Kirika et al., 2020).

Remote sensing confirms this pattern basin-wide: a nearly continuous ring of "Unhealthy" to "Very Unhealthy" water quality encircles the lake's margins, encompassing similarly degraded conditions in Winam Gulf near Kisumu and Mwanza Gulf.

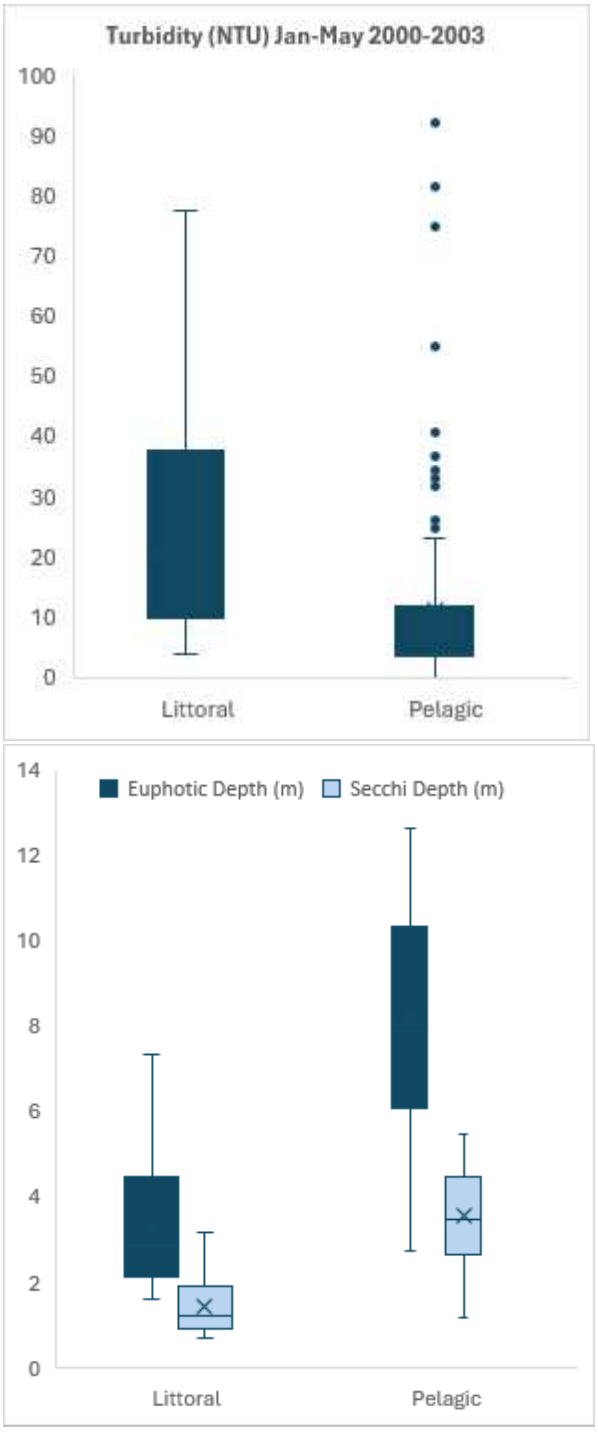


Figure 5-16. *[Left] Turbidity in Jan-May 2000-2003 and [Right] Euphotic and Secchi Depths in June-July, 2025 in Lake Victoria. Pelagic (offshore) areas have lower turbidity and higher transparency than littoral (nearshore) areas (data source: LVBC, 2025).*

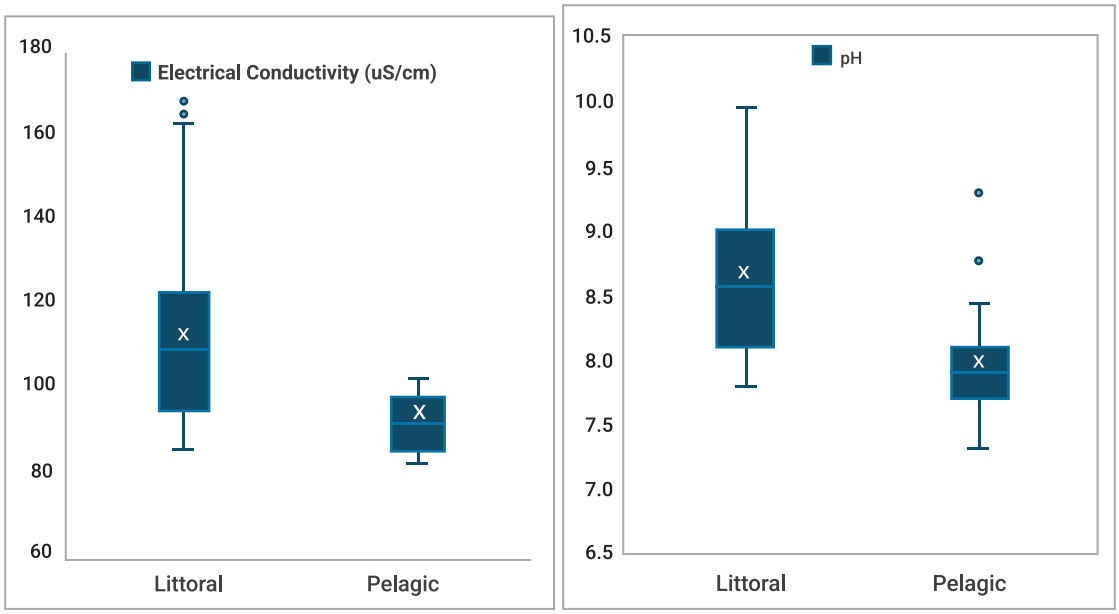


Figure 5-17. *[Left] Electrical conductivity and [Right] pH in nearshore and offshore zones of Lake Victoria, Feb–Apr 2000–2003. Higher values nearshore reflect greater terrestrial inputs from catchment runoff, and higher algal photosynthesis. (data source: LVBC, 2025).*

5.4.4.3 Seasonal Amplification of Problems

Seasonal dynamics strongly amplify these spatial patterns. Wet seasons drive peak inflows of runoff and sewage, producing sharp rises in turbidity, nutrients, and organic loads that strip oxygen at night—making rainy periods the most acutely stressful times for nearshore ecosystems (Nakkazi et al., 2024). Offshore waters, buffered by depth and mixing, experience less immediate impact, but each seasonal pulse adds to the nutrient reservoir sustaining long-term eutrophication.

The ecological response often lags: offshore phytoplankton blooms typically intensify during late dry seasons when stratification stabilizes, while nutrient-rich gulfs experience their largest blooms weeks after peak rains, when residual nutrient surpluses coincide with calmer conditions (Onyango et al., 2024).

5.4.4.4 Mercury Contamination in Lake Victoria Nearshore Waters

During the joint LVBC-GIZ lakewide water quality monitoring cruise conducted in June-July 2025, water samples were collected from nearshore areas, preserved and later analyzed for total mercury in laboratories in Entebbe, Kisumu and Mwanza. Mercury was used as a proxy for general heavy metal contamination. The analysis results revealed significant contamination in bottom waters adjacent to major urban centers, highlighting an emerging environmental and public health concern for the Lake Victoria Basin.

The Table 5-3 below presents the site-specific results of the assessment.

Table 5-3. This Results of mercury analysis in nearshore waters. (Source: LVBC, 2025)

Site	Country	Number of Samples	Max Hg (µg/L)	Status
Kisumu Bay	Kenya	1	22.6	Critical
Musoma	Tanzania	3	10.12	Elevated
Murchison Bay	Uganda	3	3.22	Above
Emin Pasha Gulf	Tanzania	3	<0.01	Below

The site-specific results show that mercury contamination is localized in nearshore areas adjacent to major urban and industrial centers, rather than being uniformly distributed across Lake Victoria. Three of the four sites—KisumuBay, Musoma, and Murchison Bay—recorded mercury concentrations exceeding EAC standards, while Emin Pasha Gulf, a less urbanized site, showed no detectable mercury.

A strong depth-related pattern was observed: mercury was below detection in surface waters (0.5–3.0 m) but present in mid-depth to bottom waters (4.0–11.0 m) at 1.65–22.6 µg/L. This vertical distribution indicates that mercury is predominantly particle-bound, associated with suspended sediments and organic matter that concentrate near the lakebed and are periodically resuspended in dynamic nearshore environments.

Comparison with EAC Water Quality Standards

Under the EAC potable water standard (DEAS 12:2022), the maximum permissible limit for total mercury is 1.0 µg/L (0.001 mg/L), while the EAC wastewater discharge standard (DEAS 1172:2023) sets the same limit for industrial effluents. In the June–July 2025 nearshore samples, four of ten samples (40%) exceeded the potable water standard, with Kisumu Bay (22.6x) and Musoma (10.1x) showing particularly high exceedances, indicating serious environmental and public health risks in these areas.

5.4.4.5 Occurrence of methylmercury in Lake Victoria nearshore waters

Why speciation matters

The June–July 2025 LVBC–GIZ lakewide cruise quantified total mercury (THg) in nearshore waters, but did not analyse mercury speciation, particularly methylmercury (CH_3Hg^+)—a key limitation for evaluating ecological and public-health risk (Abiriga et al., 2025a, 2025b). THg cannot distinguish relatively less bioavailable inorganic forms from methylmercury, which is often a small fraction of mercury in water and sediments yet accounts for most mercury burdens in fish (Campbell et al., 2003; Abiriga et al., 2025a, 2025b). Given Lake Victoria's tropical, eutrophic setting, existing studies indicate methylmercury is likely present and spatially variable in nearshore zones (Ramlal et al., 2003; Campbell et al., 2004).

Controls on methylmercury formation in Lake Victoria

Methylmercury is generated mainly through in situ microbial methylation, driven by anaerobic communities (including sulfate- and iron-reducing bacteria and some methanogenic archaea) associated with the hgcAB gene cluster (Branfireun et al., 2020; Abiriga et al., 2023; American Chemical Society, 2025). Conditions that favour methylation include stratification-related low oxygen, high organic matter and nutrient enrichment that expand anoxic habitats, and turbid nearshore waters that weaken photodemethylation and prolong persistence (Campbell et al., 2003; Opiyo et al., 2024; Abiriga et al., 2025b). As a result, sites with moderate THg may still pose elevated risk where methylation potential is high.

Food-web transfer and exposure implications

Risk is then amplified by biomagnification through the food web. Stable isotope evidence ($\delta^{15}N$, $\delta^{13}C$) shows increasing methylmercury concentrations with trophic position, with uptake through primary consumers and small pelagics (e.g., Caridina shrimp and Rastrineobola argentea/omena) and highest burdens typically in Nile perch (Campbell et al., 2003; Opiyo et al., 2024). "Growth dilution" can moderate tissue concentrations, but reduced growth efficiency in parts of the lake (e.g., Winam Gulf) may weaken this buffering effect and increase exposure risk (Opiyo et al., 2024).

Public Health and Ecosystem Risks of Mercury Exposure

The implications for people and ecosystems are substantial. Methylmercury is a potent neurotoxin with no known safe level of exposure; in the Lake Victoria Basin, fish consumption is the dominant pathway, with greatest concern for children and pregnant women (Abiriga et al., 2025a, 2025b). Minamata-type outcomes include neurological impairment, kidney and cardiovascular effects, and developmental harm in children (Abiriga et al., 2025a, 2025b). Additional exposure may occur through unregulated mercury-containing skin-bleaching creams and, to a lesser extent, soil geophagy among some pregnant women (Knudsen, 2002; Abiriga et al., 2025a, 2025b). Ecologically, mercury can disrupt feeding and reproduction in aquatic species, with potential knock-on effects for fisheries productivity and livelihoods, including the lake's ≈ US$ 1.2 billion/year fishery.

Sources and Hotspots of Mercury and Methylmercury in Lake Victoria

Mercury inputs are linked to shoreline and catchment activities, notably:

- **artisanal and small-scale gold mining (ASGM)** – e.g., Geita and Mara/Musoma in Tanzania; goldfields near Kisumu including Karebe Gold Mining;
- **industrial effluents** – older chlorine-alkali facilities and related battery, chemical, steel/iron, and textile industries in hubs such as Kampala, Jinja, and Kisumu);
- **urban runoff and solid waste** – thermometers, electronics, and mercury-containing cosmetics); and
- **atmospheric deposition** – from burning medical and municipal waste.

These pressures create uneven risk, with hotspots most likely in nearshore embayments, wetlands, and inflow zones where organic-rich sediments and strong sediment–water interactions favour methylation. Historical measurements compiled from Lipiatou et al. (1996), Ramlal et al. (2003), and Campbell et al. (2003, 2004) indicate surface-water methylmercury spanning <0.02–1.0 ng/L, with elevated values reported in Winam Gulf and variable concentrations in Murchison Bay. Risk can be intensified by water hyacinth (Eichhornia crassipes) mats that create anoxic micro-environments supporting methylation (Ramlal et al., 2003; Campbell et al., 2004), and by mining-impacted inflows along the southern shores (e.g., near Mwanza) that deliver inorganic mercury that can be rapidly methylated in calm, organic-rich nearshore sediments (Mariki et al., 2025).

Implications for future monitoring

The absence of methylmercury measurements in the 2025 cruise limits risk interpretation and targeting of interventions. Future monitoring should therefore complement THg with speciation, ultra-trace analytical capacity, and process-based indicators, including assessment of methylation potential through detection of hgcAB in sediments (Branfireun et al., 2020; Abiriga et al., 2023; Opiyo et al., 2024). This would support earlier identification of high-risk zones before contaminants propagate through aquatic food webs..

5.4.5 Synthesis: Management Implications of Spatial and Temporal Patterns

5.4.5.1 Convergence of Evidence

The remarkable agreement between satellite observations and field measurements provides confidence in using integrated monitoring approaches. High-turbidity, high-chlorophyll areas detected from space correspond directly to nutrient-rich, algae-laden conditions measured in the field, while satellite-identified cleaner offshore zones match locations with lower nutrient and algal concentrations.

5.4.5.2 Clear Management Priorities

The integrated scientific picture provides unambiguous guidance for restoration efforts. The evidence consistently points to controlling pollution inputs at their sources, particularly in the nearshore zone where impacts are most severe and concentrated.

- Spatial targeting must focus intensively on the polluted shoreline areas and semi-enclosed bays that function as pollution hotspots, receiving the highest loads of untreated sewage, industrial effluents, and agricultural runoff.
- Temporal targeting must address both chronic sources and seasonal pulses, with interventions timed before critical runoff periods. Nutrient-specific approaches should prioritize phosphorus control as the key lever for breaking cyanobacterial dominance and shifting toward more balanced ecosystem states.

The evidence of accelerating deterioration and potential tipping points crossed around 2013 underscores the urgency of action. The contrast between offshore resilience and nearshore decline demonstrates both risk and possibility: if nutrient inputs are controlled at source, the offshore recovery suggests Lake Victoria can rebound. However, without coordinated, basin-wide measures targeting the pollution sources that degrade nearshore waters, the lake risks sliding deeper into an entrenched hypereutrophic state with mounting costs for both ecosystem health and human welfare.

The comprehensive monitoring framework established through this research provides the foundation for adaptive management, enabling real-time detection of blooms and pollution events while tracking the effectiveness of restoration interventions across this vast and complex ecosystem.

“The contrast between offshore resilience and nearshore decline demonstrates both risk and possibility: if nutrient inputs are controlled at source, the offshore recovery suggests Lake Victoria can rebound.”

5.5 Drivers and Sources of Pollution

Lake Victoria is facing mounting pressures from rapid population growth, accelerating land-use change, and intensifying human activity. These drivers have triggered widespread eutrophication, biodiversity loss, and serious public health risks, with impacts that cut across national boundaries.

This chapter examines the underlying drivers of pollution in the basin and the pathways through which they manifest as specific sources of contamination. Using the Drivers-Pressures-State-Impact-Response (DPSIR) framework, it situates demographic expansion, agricultural intensification, and industrial and urban development as the fundamental forces shaping the current pollution crisis. By analyzing how these drivers interact and propagate across the basin, the chapter underscores the urgency of coordinated, transboundary responses to safeguard Lake Victoria's ecological integrity and the livelihoods it sustains.

5.5.1 Overarching Drivers of Pollution

Pollution in the Lake Victoria Basin (LVB) is driven by powerful, interlinked socio-economic forces—rapid population growth and urbanization, and extensive land-use change. These forces interact with climate variability, which amplifies their impacts.

5.5.1.1 Population Growth and Rapid Urbanization

With over 45 million inhabitants and densities averaging 350 persons/km² (exceeding 1,200 in cities; see Chapter 2), the LVB is one of Africa's most crowded regions. Urban areas have expanded nearly tenfold since the 1980s, forming more than 100 pollution hotspots across the basin (Osinowo et al., 2022). Yet service infrastructure has lagged far behind demand: sewerage coverage remains below 10% in Kampala, about 18% in Kisumu, and 5% in Mwanza, while most solid waste is uncollected and ends up in drains and wetlands. Major cities collectively discharge millions of cubic metres of untreated wastewater each year, and informal settlements further intensify contamination through direct disposal into streams and bays. Urban sprawl also fuels deforestation and sand and clay extraction in surrounding areas, destabilizing riverbanks and wetlands (GIZ, 2025). Consequently, human settlements and industries together contribute roughly half of total basin pollution loads (CIWA, 2022a).

5.5.1.2 Land Use and Land Cover Change (LULCC)

Conversion of forests and wetlands to cropland and settlements is the main source of diffuse pollution. Between 1985 and 2014, farmland expanded by 23–48% at the expense of natural ecosystems (Osinowo et al., 2022). In Tanzania's Simiyu catchment, cropland rose from 19 to 73% of the area between 1975 and 2006, increasing runoff by 32% and sediment yield by 85% (Liyenga et al., 2015; Mtei et al., 2020). Across the basin, forest cover has declined from 51% in 1901 to below 7% by 2010 (Wasige et al., 2013), while three-quarters of wetlands are now altered or severely degraded (Olokotum et al., 2021). These changes reduce infiltration, elevate erosion and flood risks, and strip wetlands of their capacity to filter sediments and nutrients. Rising use of fertilizers and pesticides further elevates nitrate and phosphate loads in rivers, often compounded by poor rural sanitation (Mureithi, 2021). The result is a reinforcing poverty–degradation cycle where land scarcity and low productivity drive unsustainable practices that further erode natural capital (CIWA, 2022a).

5.5.1.3 Climate Variability as a Transport and Amplification Mechanism

Climate variability governs how pollutants are mobilized and delivered to the lake. Rainfall intensity strongly correlates with short-term peaks in turbidity and algal biomass, particularly in Winam Gulf and Inner Murchison Bay (Nakkazi et al., 2024). High-intensity storms trigger sediment and nutrient pulses that overwhelm lake buffering capacity, while rising lake temperatures accelerate eutrophication by stimulating microbial activity and bloom-forming cyanobacteria (Musinguzi et al., 2024). Climate change thus acts as a threat multiplier, converting chronic pressures from land and urban systems into acute water-quality crises.

5.5.2 Point Sources of Pollution

Point sources—discrete, identifiable discharges—remain major drivers of near-shore degradation in Lake Victoria. Point sources, which include municipal wastewater, industrial effluents and mining discharges, deliver an estimated ~9 000 t N yr^{-1}, ~1 600 t P yr^{-1}, and ~50 000 t BOD yr^{-1} to Lake Victoria—roughly 20–25 % of the basin's total nutrient load and less than 10 % of its sediment inflow (WORLD BANK, 2018; LVBC, 2025). Their effects, spatially concentrated in urban areas and mining sites, are ecologically severe, driving eutrophication, oxygen depletion, and heavy-metal accumulation as described in Section 5.2.

5.5.2.1 Municipal and Domestic Wastewater

Untreated or poorly treated municipal wastewater is the largest point-source pollutant. Less than 10 % of urban residents are connected to sewers—about <10 % in Kampala, ~18 % in Kisumu, and ~5 % in Mwanza—leaving most households reliant on pit latrines and septic tanks that leak during heavy rains (Nyenje et al., 2010; LVBC, 2025).

Across the basin, these discharges release roughly 6 500 t of total nitrogen (TN), 1 000 t of total phosphorus (TP), and about 50 000 t of biochemical-oxygen-demand (BOD) each year (WORLD BANK, 2018; World Bank, 2016; Wang et al., 2023). The loads are most concentrated in Murchison Bay, Winam Gulf, and Mwanza Gulf, where weak circulation traps nutrients and pathogens. In these semi-enclosed bays, eutrophication and cyanobacterial blooms are frequent, and dissolved-oxygen minima of <2 mg L^{-1} occur during calm periods (Oguttu et al., 2018). Degradation of wetlands such as Nakivubo has reduced natural filtration, allowing direct inflow of sewage and greywater into the lake. Communities drawing untreated water from shorelines face recurrent outbreaks of cholera, typhoid, and dysentery (LVBC, 2025).

5.5.2.2 Industrial Effluents

Industrial activities—including fish-processing plants, breweries, tanneries, textile and agro-industries—generate nutrient-rich and chemically contaminated effluent that often receives minimal treatment. Basin-wide, industrial sources contribute an estimated 2 500–3 000 t TN yr^{-1} and 400–600 t TP yr^{-1}, equivalent to about one-third of total point-source nutrient inputs (WORLD BANK, 2018; LVBC, 2025).

The Nile perch industry alone discharges about 1.8 million m^3 yr^{-1} of high-strength wastewater (COD ≈ 12 000 mg L^{-1}), while agro-processing effluents entering Winam Gulf via the Kisat and Auji rivers routinely exceed national standards for COD, oils, and heavy metals (Kundu et al., 2017; KIWASCO, 2018). Tanneries and metal workshops release chromium, lead, and mercury, which accumulate in sediments and biota, threatening fisheries and public health (Scheren et al., 2000). Without significant upgrades to treatment plants, industrial zones will continue to reinforce the oxygen depletion and contamination trends noted in **Section 5.2.3**.

5.5.2.3 Mining

Mining—both large-scale and artisanal—adds a qualitatively different pollution burden to the Lake Victoria Basin. While it contributes little to nutrient enrichment, it is a major source of heavy metals and persistent toxins. Large operations at Geita, North Mara, and Bulyanhulu (Tanzania)

and smaller ones in Busia–Kakamega (Kenya) dominate formal mining, while artisanal and small-scale mining (ASM) is widespread across all five riparian states.

Annual mercury emissions from ASM in north-western Tanzania are estimated at 15–30 t yr^{-1}, among the highest in Africa (Mariki et al., 2023). Comparable contamination has been recorded in Kenya and Uganda, where mercury levels in soils and groundwater near mining zones exceed WHO thresholds (Mugo et al., 2023; UNDP, 2012). Soils around Geita contain cadmium concentrations more than 400 times the national standard (Yohannes et al., 2024), while sediments in Mwanza Gulf record elevated lead (≈ 55 ppm) and zinc (≈ 84 ppm) (Kishe & Machiwa, 2003). About 10 % of Nile perch sampled across the basin show mercury concentrations above WHO food safety limits (Ikingura & Akagi, 2003).

These contaminants accumulate in bottom sediments and aquatic biota, forming long-lived toxic reservoirs that can be remobilized during floods or dredging events. Unlike nutrients, heavy metals do not degrade and can persist for decades, posing chronic risks to aquatic ecosystems, fisheries, and human health. Recent basin-wide monitoring (LVBC, 2025) confirms that most metals remain below detection limits in open waters but that copper (0.001–0.003mg L^{-1}) and arsenic (≈ 0.001 mg L^{-1}) persist near inflow and mining-affected zones.

5.5.3 Non-Point (Diffuse) Sources of Pollution

Diffuse pollution dominates Lake Victoria's total pollutant load, arising from countless dispersed activities that collectively exceed point-source discharges. Non-point sources generate over 70 % of sediment and about 65 % of nutrient loads to Lake Victoria (WORLD BANK, 2018; LVBC, 2025). Major contributors include agriculture, livestock waste, on-site sanitation leakage, urban stormwater, atmospheric deposition, and fish-processing waste. Their effects are widespread and seasonal—intensifying during the wet-season "first flush" and declining during dry months—closely mirroring the patterns in **Section 5.2**.

5.5.3.1 Agricultural Runoff and Erosion

Conversion of forests, grasslands, and wetlands to farmland has been the root driver of nutrient enrichment and eutrophication. Rain-fed cultivation on steep, deforested slopes exposes soils to erosion and runoff carrying sediments, nutrients, and pesticide residues.

The Nzoia, Yala, and Nyando rivers each deliver 1.4–2.5 million t yr^{-1} of sediment to the lake (World Bank, 2016; Kithiia, 2012), while the Kagera contributes about 1.4 million t yr^{-1} (NBI, 2012). Agricultural catchments account for over 80 % of total sediment inflow (~3.2 million t yr^{-1}; LVBC, 2025). Sediments carry attached phosphorus and organic matter, degrading water clarity and benthic habitats.

Diffuse nutrient exports are similarly high, with 34 000 t N yr^{-1} and 3 200 t P yr^{-1} entering the lake (WORLD BANK, 2018; World Bank, 2016). Excess fertilizer use, pesticide application, and soil erosion remain the principal causes of eutrophication and algal blooms.

5.5.3.2 Livestock and Rural Settlements

Livestock keeping and scattered rural settlements contribute major microbial and nutrient loads. Animal wastes and unlined pit latrines leach E. coli, nitrates, and ammonium into watercourses, with observed E. coli densities reaching 10^3–10^5 MPN 100 mL^{-1} in the Yala, Rwizi, and Kagera basins (Raburu, 2012; Turyahabwe et al., 2013). These diffuse sources contribute roughly 25–30 % of total nitrogen and phosphorus inflows (WORLD BANK, 2018). Manure volatilization also enhances atmospheric nitrogen deposition.

5.5.3.3 Urban Stormwater, Plastics, and Fish-Processing Waste

Urban runoff from Kisumu, Mwanza, and Kampala mobilizes sediments, hydrocarbons, nutrients, trace metals (Pb, Cu, Zn), and plastics from roads, roofs, and dumpsites. Wet-season events supply about 15–20 % of nutrient inflows and 0.3

million t yr^{-1} of solids (World Bank, 2016). In Kisumu, about 12 t of plastic enter the lake annually, while abandoned fishing nets ("ghost gear") form roughly 86 % of lakebed debris (Biginagwa et al., 2016; KIWASCO, 2018). These plastics fragment into micro- and mesoplastics, harming fish and releasing toxic additives.

The fish-processing sector adds further diffuse waste—about 150 000 t yr^{-1}, of which 80 % is discarded untreated—raising BOD and nutrient levels in nearshore waters (Malowa, 2023).

5.5.3.4 Atmospheric deposition

Atmospheric deposition is a major pathway through which nutrients enter Lake Victoria and has become a critical driver of eutrophication across the basin. Owing to the lake's hydrological configuration, approximately 80–82% of its water input is derived directly from rainfall, giving atmospheric inputs a disproportionate influence on the lake's nutrient balance (LVBC, 2021; Bakayoko et al., 2021). Over recent decades, increasing atmospheric inputs of nitrogen and phosphorus—linked to land-use change, agricultural intensification, biomass burning, and urbanisation—have contributed significantly to the lake's shift from an oligotrophic to a persistently eutrophic state (Scheren et al., 2000; Tamatamah et al., 2005; Pasche et al., 2025).

Lake Victoria's shallow depth and large surface area create an extensive air–water interface that enhances the interception and retention of atmospherically transported nutrients. Long water residence and flushing times further promote nutrient accumulation, limiting natural dilution and removal processes (LVBC, 2021; Pasche et al., 2025).

Atmospheric deposition constitutes a dominant component of the lake's nitrogen budget, with total inputs estimated at approximately 15 kg N ha^{-1} yr^{-1} from combined wet and dry deposition (Bakayoko et al., 2021). Wet deposition is dominated by ammonium, reflecting strong agricultural and livestock influences, while dry deposition—linked to biomass burning and dust transport—accounts for roughly 40–45% of total atmospheric nitrogen inputs (Bakayoko et al., 2021; Vuai et al., 2013; Hickman et al., 2021).

Atmospheric phosphorus deposition is particularly significant, accounting for more than half of the lake's total phosphorus load. Total atmospheric phosphorus inputs are estimated at approximately 13,500 tonnes yr^{-1}, with dry deposition contributing around 70–75% of this load, primarily in particulate form (Tamatamah et al., 2005; Pasche et al., 2025). Wet deposition contributes a smaller share of total phosphorus mass but delivers more bioavailable soluble reactive phosphorus.

The atmospheric nutrient burden over Lake Victoria reflects a combination of local emissions and regional transport. Biomass burning associated with land clearing and agricultural practices is a major source of particulate phosphorus and organic nitrogen, particularly during the dry season (Vuai et al., 2013). Agricultural activities and livestock production contribute reduced nitrogen species through ammonia volatilisation, while urban and peri-urban areas add oxidised nitrogen from transport and industrial sources (Scheren et al., 2000; Hickman et al., 2021). Deposition rates are highest near urban centres and intensively farmed areas, declining toward offshore regions, though background atmospheric loading remains significant across the open lake.

The dominance of atmospheric nutrient inputs has reinforced eutrophication, manifested through increased algal biomass, reduced water transparency, and recurrent harmful algal blooms. Because a substantial share of nutrient loading originates from diffuse and airborne sources, effective basin management requires integrated approaches that address land use, biomass burning, agricultural practices, and broader airshed governance alongside conventional water-quality and wastewater interventions (LVBC, 2021; Pasche et al., 2025).

5.5.3.5 Legacy Inputs

In former mining zones such as Geita, North Mara, and Migori, contaminated floodplain soils continue to release Hg, Cd, and Pb into waterways (Kishe & Machiwa, 2003; Mariki et al., 2023).

Textbox 5-1: Comparison of point and non-point pollution

Point sources and non-point sources contribute differently to Lake Victoria's pollution burden. Point sources—mainly municipal and industrial effluents—create acute hotspots of nutrient and toxin loading in bays and gulfs near urban centers, with immediate effects such as eutrophication, algal blooms, and hypoxia. In contrast, diffuse non-point sources dominate the overall basin-wide load, with agricultural runoff, sedimentation, and atmospheric deposition accounting for the majority of nitrogen, phosphorus, and sediment fluxes entering the lake. Solid waste pollution, though smaller in load, is highly visible and persistent, particularly around landing sites. Addressing both categories simultaneously is essential: point sources require targeted wastewater and industrial controls, while non-point sources demand catchment-wide land stewardship and pollution prevention.

5.5.4 Hazardous Waste, POPs, and E-Waste Management

As discussed in **Section 5.2.1.3**, hazardous waste, Persistent Organic Pollutants (POPs), and electronic waste (e-waste) are emerging but increasingly critical threats to water quality in the Lake Victoria Basin (LVB). Their rise is driven by rapid urbanization, industrialization, and informal economic activity. Major sources include untreated industrial and municipal effluents, agrochemical runoff containing legacy POPs pesticides, and mercury releases from artisanal and small-scale gold mining (UNEP, 2016; World Bank, 2021). These largely unregulated waste streams fall outside the effective reach of global conventions such as Basel, Bamako, and Stockholm, which mainly target formal industrial and municipal systems.

Evidence from basin studies shows worrying contamination levels. In Kenya's Winam Gulf, sediment concentrations of dioxin-like PCBs reach 17.4–812 pg g^{-1} and dioxins/furans 38–860 pg g^{-1}—comparable to heavily industrialized regions (UNEP, 2016). Legacy POPs pesticides, including DDT and endosulfan, persist in the Yala, Nzoia, and Nyando basins, contaminating aquatic food webs.

National inventories expose significant data and capacity gaps. Rwanda holds the most comprehensive record—122 t of PCB oil, 250 t of contaminated soil, 3 t of POPs pesticides, and 1 t of mercury (REMA, 2022)—whereas Uganda and Tanzania rely on outdated data and Burundi's records remain largely qualitative (Basel Convention Secretariat, 2014).

E-waste is among the fastest-growing hazardous waste streams, with East Africa generating about 128 kt in 2021 (E-Waste Monitor, 2024). Rwanda's recycling facility (7,000–10,000 t yr^{-1} capacity) functions as a regional hub under the East African Communications Organisation's 2022–2027 strategy. Yet a "Bamako Gap" persists: Rwanda is not Party to the Bamako Convention, while Tanzania, Uganda, and Burundi are—creating legal uncertainty over cross-bor-

der waste transfers and risking accumulation in countries lacking adequate disposal capacity.

Conversely, implementation of the Stockholm Convention is a regional success. All five countries are updating their National Implementation Plans (NIPs) to include emerging POPs such as PBDEs from e-waste; REMA, 2022). Priority actions include harmonizing legal frameworks to close the Bamako Gap, institutionalizing a regional hub-and-spoke e-waste model with sustainable financing, and standardizing hazardous-waste inventories through the NIP process.

5.5.5 Synthesis of Pollution Loads and Concluding Remarks

Pollution in the Lake Victoria Basin (LVB) arises from deeply interconnected demographic, economic, and environmental processes that have outpaced the region's governance and infrastructure capacities. Rapid population growth and urban expansion have generated concentrated point-source effluents from municipal, industrial, and mining activities, while extensive land-use change and agricultural intensification have unleashed vast diffuse loads of sediments, nutrients, and pathogens. Climate variability further magnifies these pressures, transforming chronic stress into acute ecological crises such as algal blooms, hypoxia, and fish kills.

Point-source discharges, though spatially localized, exert disproportionate impacts in enclosed bays and gulfs where circulation is weak, creating persistent eutrophication and contamination hotspots around Kampala, Kisumu, and Mwanza. By contrast, non-point sources—agriculture, erosion, livestock waste, and urban runoff—dominate basin-wide loading, accounting for more than two-thirds of sediment and nutrient inflows (**Table 5-4**). Emerging contaminants—including plastics, hazardous waste, and Persistent Organic Pollutants (see Section 5.2.1.3)—now add a new dimension to the pollution challenge, with legacy pesticides, PCBs, and e-waste residues infiltrating aquatic food webs and posing long-term health and ecological risks.

Together, these dynamics illustrate a classic **DPSIR** sequence: population and land-use pressures (Drivers) produce widespread effluents and waste streams (Pressures) that degrade water quality and ecosystems (State), undermining fisheries, livelihoods, and public health (Impacts). The persistence of weak enforcement, fragmented data systems, and gaps in regional conventions (e.g., the "Bamako Gap") limits effective policy Responses.

Addressing this crisis requires integrated, transboundary action: strengthening wastewater and industrial pollution control; promoting catchment-wide soil and nutrient management; restoring wetlands and riparian buffers; and harmonizing hazardous-waste governance under the Basel, Bamako, and Stockholm frameworks. Only through coordinated regional stewardship—anchored in sound science, shared monitoring, and equitable investment—can the LVB transition from reactive pollution control to proactive ecosystem protection and sustainable resource use.

Table 5-4. Synthesis of Pollution Loads

Source Category	Total Nitrogen (TN) (tonnes/year)	Total Phosphorus (TP) (tonnes/ year)	Contribution to BOD Load (%)	Source(s)
Non-Point Sources				
Atmospheric Deposition	167,650	39,978	–	(LVEMP, 2005)
Riverine Loads / Runoff	38,828	9,270	51.6%	(GIZ, 2025; LVEMP, 2005)
Point Sources				
Municipal / Urban Runoff	4.3*	1.9*	36.8%	(GIZ, 2025; LVEMP, 2005)
Industrial Effluents	–	–	11.5%	(GIZ, 2025)
Mining (Heavy Metals, no TN/TP estimate)	–	–	Localized hotspots of Hg, Cd, Pb, Zn contamination	(Mariki et al., 2023; Yohannes et al., 2024; Mugo et al., 2023)
Total Estimated Load	~206,482	~49,250	100%	

Note: The point source TN and TP figures from LVEMP (2005) appear exceptionally low and likely represent only a fraction of the total point sources quantified in that specific study. They are included for consistency but should be interpreted as a significant underestimate of the true point source load.

5.6 Impacts of Water Quality Degradation

The degradation of water quality in the Lake Victoria Basin is not only an ecological crisis but also a profound socio-economic and public health challenge. This section examines how declining water quality reverberates across multiple dimensions: altering ecological processes, reducing biodiversity and fisheries productivity, threatening drinking water security, increasing disease burdens, and imposing escalating economic costs on key sectors such as tourism, industry, and real estate. By tracing these linkages, the section demonstrates that water quality decline is more than an environmental concern—it directly undermines livelihoods, food security, and human well-being across the basin. Understanding these impacts is therefore critical for shaping effective policy responses, guiding investment priorities, and mobilizing collective action to safeguard the basin's future

5.6.1 Ecosystem Impacts

The most severe effects of water quality decline are evident within Lake Victoria's ecosystem. Anthropogenic pollution—driven mainly by nutrient enrichment—has triggered profound physical, chemical, and biological transformations that have fundamentally altered the structure and function of this globally significant freshwater body.

5.6.1.1 Foundational Shift: Eutrophication, Hypoxia, and Anoxia

Lake Victoria has entered a permanently eutrophic state, marked by persistent algal blooms, hypoxia, and anoxia. Sustained phosphorus and nitrogen inflows from agriculture, sewage, and industry fuel algal blooms whose decay depletes oxygen in bottom waters (International Lake Environment Committee, 2006; Njiru et al., 2012).

Currently, 40–50% of the lake's bottom waters are oxygen-depleted and uninhabitable (Njiru et al., 2012). Loss of benthic habitat undermines fish spawning, disrupts nutrient cycling, and promotes phosphorus release from sediments, further reinforcing eutrophication. Seasonal stratification and mixing (see **Section 5.3**) deepen this condition.

5.6.1.2 Acute Manifestations: Hypoxic Events and Fish Kills

Beyond chronic oxygen depletion, periodic upwelling events cause mass fish kills. Between June and August, strong winds displace surface waters, bringing sulphide-rich, oxygen-poor deep water to the surface (GIZ, 2025; Olingo, 2023). Dissolved oxygen frequently drops below the 3 mg/L survival threshold.

Although fish kills were noted as early as 1927, their frequency and spatial extent have sharply increased with changing wind regimes and climate variability (Olingo, 2023). Aquaculture is especially at risk: high stock densities and organic waste elevate oxygen demand. In September–November 2022, upwelling in Kisumu and Homa Bay killed an estimated 364 million fish, devastating livelihoods and local markets (GIZ, 2025; Olingo, 2023). A chronology of major fish-kill events linked to upwelling, hypoxia, and algal blooms is presented in **Table 5-5**.

Table 5-5. Documented mass fish kill events in Lake Victoria (1990–2025), with a focus on incidents linked to upwelling, hypoxia (low dissolved oxygen), and algal blooms.

Date	Location(s)	Primary Cause	Key Observations	Estimated Fish Mortality	Estimated Economic Loss (USD)	Source(s)
2016	Anyanga & Nyenye-Got beaches, Kenya	Reduced DO (hypoxia), possible upwelling	Poor water circulation in cages due to algae & feed residues; suspected upwelling around cages	Not specified	Not specified	Olingo (2023)
Jan–Feb 2021	Uganda (Wakiso, Buikwe, Buvuma, etc.; also reported in Kenya & Tanzania)	Upwelling of hypoxic water (stratification breakdown)	Wild Nile perch die-off; mostly large Nile perch found floating ashore; officials noted only Nile perch (high O_2 demand) were affected, pointing to oxygen depletion rather than toxin	>100 tonnes of fish (mostly Nile perch)	~$400,000 (lost market value)	Monitor (2021); African Arguments (2022)
Nov 2022	Kisumu & Homa Bay counties, Kenya	Upwelling of low-oxygen deep water	DO < 3 mg/L; surface temp ~28 °C; increased suspended sediment noted. Massive die-off in cage farms (nearshore); event coincided with algal bloom and water hyacinth decay reducing oxygen	~364 million farmed tilapia	KSh 900 million to 1.4 billion (≈ $7.2–11.4 million)	GIZ (2025); Olingo (2023)
Early 2023	Lake Victoria (Kenya)	Upwelling (recurrence of 2022 event)	Continuation of late-2022 upwelling phenomenon; thousands of caged fish died suddenly (no major algal bloom reported at this time). Losses spanned multiple farms.	"Thousands of fish" (caged tilapia)	(Part of ~$7 million total loss in 2022–2023)	Alliance for Science (2023)
Oct 2024	Mulukoba Beach (Busia), Kenya	Reduced DO in cages (stagnation from crowding)	Cages placed too closely in shallow bay; poor water circulation led to oxygen depletion. ~50 tonnes of farmed tilapia died across ~300 cages, crippling local fish businesses	~50 tonnes of caged tilapia	~KSh 5 million (≈ $35,000)	Kenyans.co.ke (2024)

5.6.1.3 Proliferation of Water Hyacinth

Eutrophication has also spurred the spread of water hyacinth (***Eichhornia crassipes***), introduced via the Kagera River in the late 1980s. By 1998, it covered up to 20,000 ha of sheltered bays, notably Winam Gulf and Murchison Bay (NASA Earth Observatory, 2006). Biological control (weevils) and removal reduced coverage in the early 2000s, yet periodic resurgences persist as nutrient inflows continue.

Hyacinth mats block sunlight, suppress native vegetation, and deplete oxygen during decay. They trap debris, obstruct navigation and fishing, and provide breeding sites for mosquitoes and snails—heightening malaria and schistosomiasis risks (Njiru et al., 2012; GIZ, 2025).

5.6.1.4 Phytoplankton Densities and Community Structure in Lake Victoria

The joint lake cruise organized by LVBC and GIZ in June-July 2025 included a comprehensive phytoplankton survey covering 44 sampling stations in the three riparian countries (Kenya, Tanzania, and Uganda), with samples collected at various depths. Phytoplankton densities in the surface water column (0.5m depth) have been analysed for this report. The survey recorded 106 unique phytoplankton taxa comprising three major taxonomic groups: Cyanobacteria, Chlorophyta (green algae), and Bacillariophyta (diatoms). The analysis revealed significant spatial heterogeneity in algal cell densities, pronounced cyanobacterial dominance, and concerning prevalence of potentially toxigenic species across the lake basin.

Spatial Distribution and Density Patterns

Phytoplankton densities exhibited marked spatial variability across the lake, with littoral zones consistently demonstrating substantially higher cell concentrations compared to pelagic waters (Figure 5-18). Tanzania littoral stations recorded the highest mean density at 45,486 cells/mL, followed by Uganda littoral at 41,488 cells/mL and Kenya littoral at 27,265 cells/mL. In contrast, pelagic zones exhibited significantly lower densities with reduced spatial variability. Tanzania pelagic waters recorded a mean density of 15,029 cells/mL, Uganda pelagic 14,484 cells/mL, and Kenya pelagic 9,101 cells/mL. The 2- to 5-fold lower densities in offshore waters reflect conditions characteristic of pelagic environments where nutrient availability is limited compared to littoral zones that receive direct terrestrial runoff and anthropogenic inputs. However, notably high densities were recorded at several pelagic stations, particularly Tanzania TP 07 (59,868 cells/mL) and Uganda UP 01 (41,422 cells/mL), suggesting nutrient enrichment extends into offshore areas through lake circulation patterns. The substantial variability observed in littoral densities indicates pronounced spatial heterogeneity in nutrient loading from adjacent catchments.

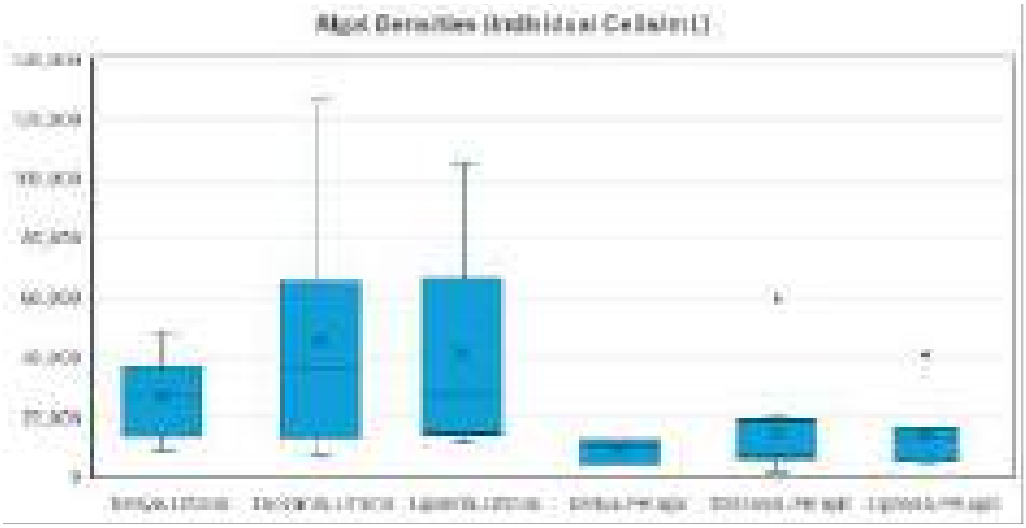


Figure 5-18. *Phytoplankton densities in littoral and pelagic environment in Lake Victoria in June-July 2025. (Source: LVBC, 2025).*

Phytoplankton Community Composition and Cyanobacterial Dominance

Cyanobacteria exhibited overwhelming dominance across Lake Victoria, representing the primary component of phytoplankton biomass in all zones surveyed (Figure 5-19). Littoral zones demonstrated the most extreme cyanobacterial dominance, with Uganda littoral communities comprising 91.2% cyanobacteria, Tanzania littoral 87.7%, and Kenya littoral 80.7%. Remarkably, 31.8% of all sampling stations (14 out of 44) exhibited greater than 85% cyanobacterial dominance, indicating severe water quality degradation across substantial portions of the lake.

While cyanobacteria remained dominant in pelagic zones, their proportional representation was moderately reduced compared to littoral areas: Uganda pelagic 81.9%, Tanzania pelagic 70.3%, and Kenya pelagic 53.0%. Kenya pelagic waters exhibited the most balanced community structure, with diatoms comprising 34.5% and green algae 12.6% of the assemblage. This enhanced diversity likely reflects distinct hydrological conditions, including upwelling dynamics and mixing patterns that create favorable conditions for diatom proliferation in Kenya's offshore waters.

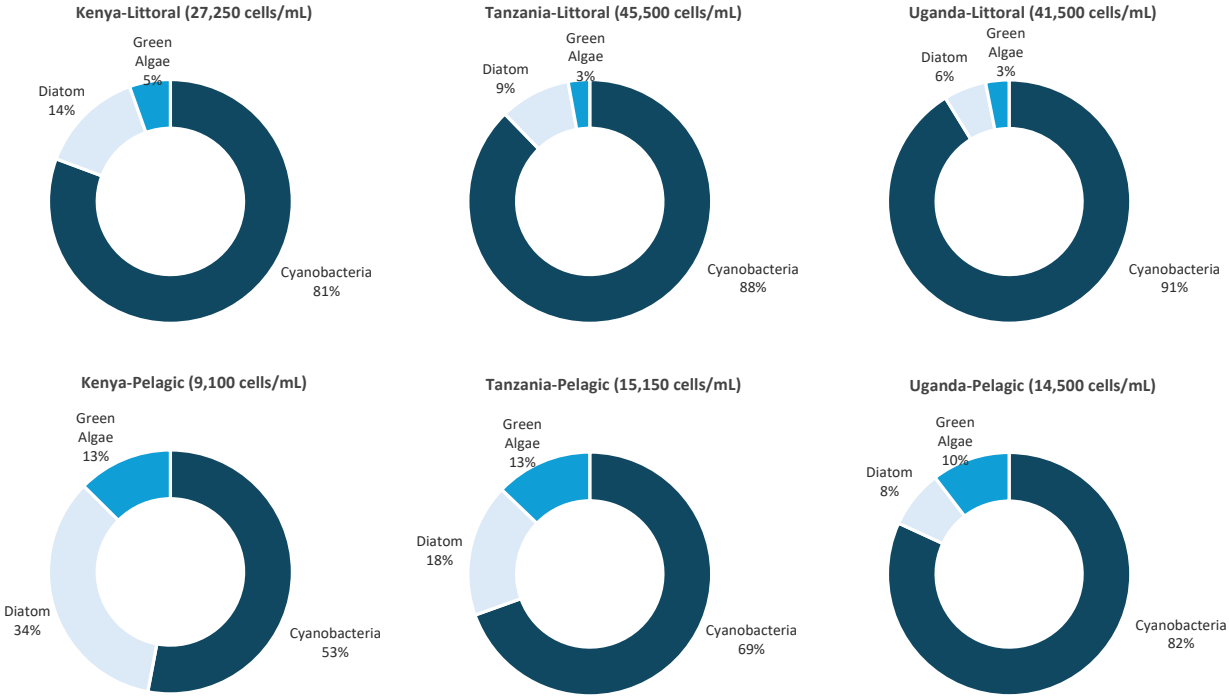


Figure 5-19. *Phytoplankton community composition in surface (0.5 m depth) littoral and pelagic zones in the Kenyan, Tanzanian and Ugandan sectors of Lake Victoria (Source: LVBC, 2025).*

Green algae contributed relatively minor proportions to total phytoplankton density across all zones, ranging from 2.8-5.4% in littoral zones and 10.4-12.6% in pelagic zones. Diatoms showed higher representation in littoral zones (5.7-13.9%) and pelagic zones (7.7-34.5%), with Kenya exhibiting the highest diatom abundances in both habitat types. Compared to the Kenyan and Tanzanian waters, the Ugandan part of Lake Victoria exhibits a relatively lower abundance of diatoms within the algal community. This pattern is likely attributable to a combination of stronger eutrophication and urban nutrient loading in nearshore Ugandan waters, possible silica limitation, and physical conditions such as reduced mixing or higher turbidity that favour non-diatom algal groups, particularly cyanobacteria. The lake-averaged algal community composition in littoral and pelagic zones is shown in Figure 5-20.

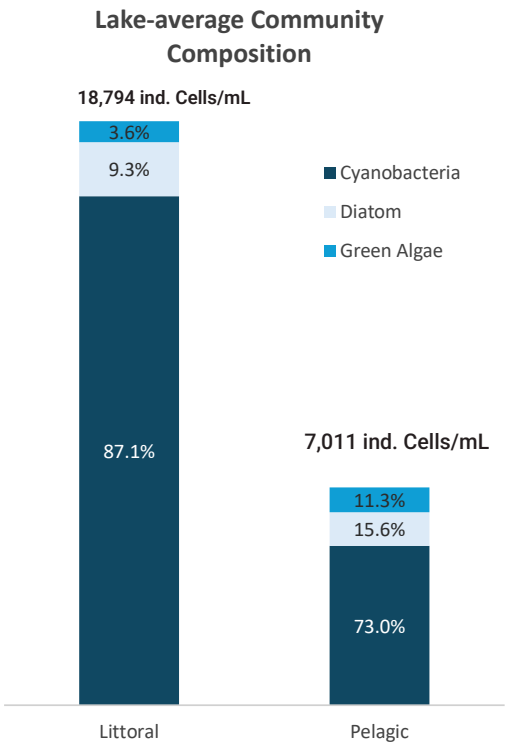


Figure 5-20. *Lake-averaged algal community composition in littoral and pelagic zones in Lake Victoria.*

The pervasive cyanobacterial dominance observed throughout Lake Victoria is characteristic of hyper-eutrophic tropical lakes and reflects elevated nutrient concentrations, particularly phosphorus and nitrogen, stemming from agricultural runoff, inadequately treated domestic and industrial wastewater, and atmospheric deposition. The shift toward cyanobacterial-dominated communities represents a fundamental alteration from the lake's historical phytoplankton assemblage structure prior to widespread anthropogenic nutrient enrichment.

Species Composition and Diversity Patterns

Detailed taxonomic analysis across 44 stations identified 106 unique phytoplankton taxa, with species richness varying substantially among taxonomic groups and habitat types. Green algae exhibited the highest species diversity, with 30-34 taxa in pelagic waters and 27-30 taxa in littoral zones across the three countries. Cyanobacteria comprised 12-27 species depending on zone and country, while diatoms demonstrated relatively lower diversity with 8-13 species per zone.

Despite the high species richness, phytoplankton biomass was concentrated in a limited number of dominant taxa. *Microcystis flos-aquae* emerged as the overwhelmingly dominant species lake-wide, with a commulative concentration of 384,270 cells/mL across all sampling stations and occurrence at 97.7% of sites (43 of 44 stations). This near-ubiquitous distribution underscores the species' ecological success under current lake conditions and represents a critical public health concern given its capacity to produce hepatotoxic microcystins.

Littoral zones harbored 30 cyanobacterial species, including potentially toxigenic genera such as *Microcystis (M. flos-aquae, M. aeruginosa), Anabaena (A. flos aquae, A. spirodes), Cylindrospermopsis (C. raciborskii, C. africana),* and various *Planktolyngbya* species. The presence of *Cylindrospermopsis raciborskii,* a known producer of *cylindrospermopsin* toxin, is particularly concerning as this species has been associated with severe human health impacts in other tropical water bodies.

Green algae diversity was represented by 46 species in littoral zones and 44 species in pelagic zones, including *genera Ankistrodesmus*, *Scenedesmus*, *Pediastrum, Coelastrum, Kirchneriella*, and *Staurastrum*. The endemic species *Rhizosolenia victoriae* was recorded in both littoral and pelagic habitats, though at relatively low abundances compared to dominant cyanobacteria.

Diatom assemblages comprised 15 species in littoral zones and 14 species in pelagic zones, dominated by *Aulacoseira nyassensis*, *Nitzschia acicularis*, *Cyclotella* species *(C. kutzingiana, C. meneghiniana)*, and *Synedra cunningtoni*i. The dominant species in the lake are shown in Tables 5-6 and 5-7.

Table 5-6. **Dominant phytoplankton species in littoral (nearshores) waters of Lake Victoria (Source: LVBC, 2025).**

Cyanobacteria	Green Algae	Diatom
Anabaena flos aquae	*Actinastrum hantzschii*	*Aulacoseira nyassensis*
Anabaena spirodes	*Ankistrodesmus falcatus*	*Cryptomonas sp*
Aphanocapsa sp	*Ankistrodesmus falcatus var. mirabilis*	*Cyclotella kutzingiana*
Merismopedia punctata	*Ankistrodesmus setigera*	*Nitzschia acicuralis*
Merismopedia tenuissima	*Ceratium brachyceros*	*Synedra cunningtonii*
Microcystis flos-aquae	*Coelastrum cambricam var.nasutum*	
Planktolyngbya limnetica	*Coelastrum cambricum*	
Planktolyngbya tallingii	*Coelastrum microporum*	
	Kirchneriella contorta	
	Kirchneriella obesa	
	Pediastrum simplex	
	Pediastrum simplex var duodenarium	
	Pediastrum tetras	
	Rhizosolenia victoriae	
	Scenedesmus acuminatus fa. woloszynska	
	Scenedesmus acunae	
	Scenedesmus obliquus	



Figure 5-21. *An algal bloom on Lake Victoria in Winum Gulf, Kenya. (Source: Kings College London).*

Table 5-7. **Dominant phytoplankton species in pelagic (offshore) waters of Lake Victoria (Source: LVBC, 2025).**

Cyanobacteria	Green Algae	Diatom
Anabaena flos aquae	*Ankistrodesmus falcatus*	*Aulacoseira nyassensis*
Aphanocapsa sp	*Ankistrodesmus falcatus var. mirabilis*	*Cryptomonas sp*
Chroococcus limneticus	*Ankistrodesmus falcatus var. setiformis*	*Cyclotella kutzingiana*
Merismopedia punctata	*Coelastrum cambricum var. nasatum*	*Cyclotella meneghiniana*
Merismopedia tenuissima	*Coelastrum microporum*	*Nitzschia acicuralis*
Microcystis aeruginosa	*Crucigenia pulchra*	*Synedra cunningtonii*
Microcystis flos-aquae	*Kirchneriella contorta*	
Planktolyngbya circumcreta	*Pediastrum simplex*	
Planktolyngbya limnetica	*Pediastrum tetras*	
Planktolyngbya tallingii	*Rhizosolenia victoriae*	
	Scenedesmus acuminatus	
	Scenedesmus acunae	

Public Health Risks from Toxigenic Cyanobacteria

The prevalence of potentially toxigenic cyanobacterial species across Lake Victoria poses severe public health risks to the estimated 45 million people residing in the basin who depend on the lake for drinking water, fisheries, and other ecosystem services. *Microcystis flos-aquae,* detected at 97.7% of sampling stations, is a well-established producer of microcystin hepatotoxins that can cause acute liver damage, chronic liver disease, and have been classified as possible human carcinogens by the World Health Organization. The species' near-ubiquitous distribution and numerical dominance indicate that microcystin contamination is likely widespread throughout the lake.

Anabaena flos aquae, present in 38.6% of stations, produces anatoxins (neurotoxins) and saxitoxins (paralytic shellfish poisoning toxins) in addition to microcystins. The presence of *Cylindrospermopsis raciborskii,* a producer of cylindrospermopsin toxin, further compounds the toxin exposure risks. Cyanotoxins can contaminate drinking water supplies, bioaccumulate in fish tissues, and pose occupational health hazards to fishers and water resource users. Water utilities drawing water from the lake require enhanced treatment processes capable of removing cyanobacterial cells and dissolved toxins.

Ecological Consequences and Fisheries Impacts

Cyanobacteria-dominated phytoplankton communities have important implications for ecosystem functioning and fisheries productivity in Lake Victoria. As cyanobacteria are generally a low-quality food source for zooplankton, their dominance can weaken energy transfer through the food web, with downstream effects on fish production.

High cyanobacterial densities, particularly in nearshore areas, increase the risk of localized oxygen depletion during night-time respiration and decomposition of algal biomass. Such events can stress or kill fish—especially juveniles in nursery habitats—and disrupt benthic communities that support nutrient cycling.

Changes in phytoplankton composition may also influence the nutritional quality and safety of key commercial species such as Nile perch and Nile tilapia. Potential accumulation of cyanotoxins in fish tissues raises food safety and market concerns, with possible implications for the livelihoods and food security of communities dependent on Lake Victoria fisheries.

Management Recommendations and Nutrient Control Strategies

Mitigating cyanobacterial blooms and restoring balanced phytoplankton communities in Lake Victoria requires sustained reduction of nutrient inputs from both point and non-point sources across the basin.

Key required actions include upgrading municipal wastewater treatment to improve nutrient removal, strengthening integrated catchment management to reduce agricultural runoff, and enforcing industrial effluent standards. These measures should be supported by enhanced lake-wide monitoring systems, including early warning for harmful blooms and routine cyanotoxin surveillance in water supplies and fish. Sub-basin-specific nutrient management plans are needed to reflect local land use and pollution pressures.

While implementation will demand significant investment and coordination among riparian countries, proactive nutrient control is essential to safeguard public health, fisheries livelihoods, ecosystem services, and the long-term sustainability of Lake Victoria.

5.6.1.5 Biodiversity Loss and Food Web Collapse

Lake Victoria has undergone one of the most dramatic freshwater biodiversity losses worldwide. Of >500 endemic haplochromine cichlids, about half are extinct and 76 % of survivors are threatened (Verschuren et al., 2002). The food web is now dominated by just three species—Nile perch (***Lates niloticus***), Nile tilapia (***Oreochromis niloticus***), and silver cyprinid dagaa (***Rastrineobola argentea***) (GIZ, 2025). Nile perch predation decimated cichlids, while eutrophication and hypoxia eliminated refugia. The loss of algal-grazing and detritus-feeding cichlids removed natural phytoplankton controls, intensifying eutrophication and oxygen depletion. This feedback loop of predation, hypoxia, and reduced regulation underpins the lake's continuing ecological instability (Njiru et al., 2012).

5.6.2 Economic Impacts

The degradation of Lake Victoria's ecosystem imposes escalating economic costs on Partner States, industries, and communities. These are reflected in rising public expenditures, losses in fisheries and tourism, and erosion of the region's natural capital.

5.6.2.1 Rising Water Treatment Costs

Deteriorating raw water quality has sharply increased municipal and industrial treatment expenses. High turbidity, algal biomass, and organic matter now demand more intensive filtration, chemical dosing, and energy use (Okwany, 2019). At Uganda's Ggaba plant, the monthly chemical bill nearly doubled in a decade—about Shs500 million (US$135,000) of which is attributed to pollution (Okwany, 2019). Comparable increases are reported in Kisumu, Mwanza, and Bukoba.

Utilities also face mounting capital costs: €70 million for Kisumu's new works and €104.5 million for Mwanza upgrades. A World Bank analysis estimated that basin-wide restoration of water quality could require US$10 billion over ten years (CIWA, 2022a). For utilities with limited resources, this diverts funds from extending access, shifting the cost of pollution from polluters to consumers and taxpayers.

5.6.2.2 Damage to Fisheries

The Lake Victoria fishery—worth US$500–600 million annually and supporting about 3 million livelihoods—is in decline (Swallow & Abila, 2005; World Bank, 2018). Expanding anoxic zones have reduced habitat for Nile perch and other species, leading to a 33% fall in stocks between 2015 and 2016 (CIWA, 2022b; World Bank, 2018). In Kenya, landings dropped from 200,000 tons in 2002 to 98,000 tons in 2022 (Alliance for Science, 2023).

Periodic shocks intensify these losses: the November 2022 upwelling in Kenya killed 364 million farmed tilapia, costing over US$7 million (Alliance for Science, 2023; Olingo, 2023). Factory closures and reduced exports have followed, cutting jobs and foreign earnings. Women—who dominate post-harvest processing and trade—bear disproportionate livelihood losses (CIWA, 2022b).

5.6.2.3 Impacts on Tourism, Recreation, and Property Values

Tourism, recreation, and real estate—key non-extractive values—have also suffered. Water hyacinth mats, algal scums, foul odours, and plastic waste reduce visitor appeal and local quality of life. Hotels and restaurants in Kisumu have downsized or closed as occupancy declined (Ondiba, 2023; The Flipflopi, 2024).

Valuation studies quantify these losses: Kenyan households' willingness-to-pay for lake restoration totals KES 616.3 million (~US$5 million) annually (Mamboleo, 2022, 2023), while recreational benefits in Musoma exceed US$1 million per year (Sayer & Ade, 2021). Global evidence shows strong correlations between water clarity and waterfront property values (Hamilton & Morgan, 2010; Lee, 2013; Moore et al., 2020), suggesting that declining lake quality is already suppressing property values and eroding local wealth.

5.6.3 Human Health Impacts

The severe degradation of water quality in the basin's rivers and nearshore zones has profound and direct impacts on public health, manifesting through multiple pathways of exposure to biological and chemical contaminants. The burden falls disproportionately on the millions of people living in rural and peri-urban areas who depend directly on untreated river and lake water.

5.6.3.1 Endemic Waterborne Diseases

Microbiological contamination makes cholera, typhoid, dysentery, and diarrhoeal diseases endemic across lakeshore communities (Ali et al., 2024). In Uganda, fishing communities—less than 10 % of the population—accounted for about 58 % of cholera cases between 2011 and 2015. Floods that mobilize sewage and solid waste often trigger outbreaks. Intestinal schistosomiasis remains widespread, with prevalence reaching 40–80 % in some Kenyan lakeshore areas, while recurrent diarrhoea contributes to high childhood stunting and long-term productivity losses (Aloyce et al., 2001).

5.6.3.2 Exposure to Chemical Contaminants

Persistent chemical pollution creates additional long-term health risks. Heavy metals and persistent organic pollutants (POPs) bioaccumulate in fish—Lake Victoria's most important protein source for millions (Awange et al., 2019; Feeney et al., 2025). Mercury exposure damages the nervous system, lead and cadmium impair kidney and bone development, and chronic pesticide exposure has been linked to respiratory and reproductive disorders. Although few epidemiological studies exist, biomonitoring shows metal and pesticide concentrations in fish often exceed WHO safety limits, implying widespread but under-documented exposure across fish-consuming households.

5.6.3.3 Algal Toxins and Public Health

Eutrophication has intensified blooms of toxin-producing cyanobacteria, exposing populations through drinking, bathing, and consumption of contaminated fish (Sitoki et al., 2022; Weis, 2022). Monitoring consistently records concentrations far above global safety thresh-

olds—as summarized in **Table 5-8—**with Microcystis microcystins in Nyanza Gulf reaching 274 µg/L, over 270 times the WHO drinking-water guideline. In Kisumu Bay, 30–60 % of samples exceeded safe limits, while Cylindrospermopsis toxins in Winam Gulf and cyanobacteria densities in Murchison Bay have likewise surpassed WHO risk thresholds.

Household surveys confirm health effects: communities using untreated lake water, such as on Ukerewe Island (Tanzania), report higher gastrointestinal, skin, and respiratory illness (Kaggwa et al., 2022). Fisherfolk face chronic occupational exposure. Acute impacts include diarrhoea, rashes, and allergic reactions; prolonged exposure elevates risks of liver damage and cancer, as microcystins are classified as possible human carcinogens (Weis, 2022).

The burden is highly unequal—urban residents benefit from partial water treatment, while rural and peri-urban communities remain directly exposed, perpetuating cycles of disease and poverty (Sitoki et al., 2022).

Table 5-8. Cyanotoxin Concentrations in Lake Victoria vs. Health Guidelines

Toxin/ Parameter	Location	Measured Concentration	WHO Drinking Guideline	USEPA Guideline (Children)	Key Implication	Source(s)
Microcystins (MCs)	Nyanza Gulf	Max. 274 µg/L	1.0 µg/L	0.3 µg/L	274× WHO limit; extreme ingestion risk	Sitoki et al. (2022)
MCs (sum)	Kisumu Bay (community water)	>30–60% of samples exceed guideline	1.0 µg/L	0.3 µg/L	Chronic exposure risk, especially for children	Weis (2022)
Cylindrospermopsin	Winam Gulf	1.3 µg/L	0.7 µg/L (provisional)	0.7 µg/L	Nearly 2× drinking water standard	Bowling Green State University (2024)
Cyanobacterial cells	Murchison Bay	>1.45 × 10^6 cells/mL	100,000 cells/mL (high risk, recreational)	–	Severe risk for recreational contact	Sitoki et al. (2022)

5.6.4 Synthesis and Concluding Remarks

5.6.4.1 Synthesis of Impacts

Water-quality decline in Lake Victoria is systemic and cascading—beginning with ecological disruption and extending into economic and public-health crises.

Ecologically, persistent eutrophication, expanding hypoxia, invasive weeds, harmful algal blooms, and recurring fish kills reveal a lake in chronic distress. Biodiversity collapse has simplified the food web into a fragile system dominated by a few resilient species, reducing ecological stability and resilience.

These changes carry heavy economic costs: utilities face escalating treatment and infrastructure expenses; fisheries and aquaculture suffer periodic mass losses and shrinking stocks; and tourism and property markets are depressed by visible pollution. Hidden costs—lost productivity, health expenditures, and degraded ecosystem services—compound the burden on governments and households.

Public-health impacts are severe and unequal. Poor riparian communities, particularly women and children, face persistent exposure to pathogens, metals, pesticides, and algal toxins. The resulting disease burden deepens poverty, erodes human capital, and reinforces social vulnerability.

5.6.4.2 Concluding Reflections

Lake Victoria's water-quality decline is not merely an environmental issue but a structural development challenge undermining growth, food security, and climate resilience. Without urgent intervention, costs will continue to rise—in lost revenues, treatment bills, and diminished public trust.

Reversal demands coordinated action across sectors: urban sanitation, industrial and mining regulation, catchment stewardship, and ecosystem restoration. These must align with climate-resilience strategies and be underpinned by regional cooperation, innovative finance, and community participation in monitoring and enforcement.

5.7 Regional and National Governance of Water Quality

The degradation of water quality in Lake Victoria is one of Africa's most complex transboundary challenges, affecting more than 45 million people and threatening the world's largest inland fishery. In response, the East African Community (EAC) Partner States have built a sophisticated governance framework anchored in treaties, commissions, and coordinated programs. This chapter assesses the framework's ability to translate regional policy into effective protection, focusing on three dimensions: the legal and policy architecture, institutional capacity, and the operational effectiveness of monitoring and data systems. The analysis highlights persistent gaps between ambitious policies and practical enforcement, with significant implications for the basin's future.

5.7.1 Regional Governance Framework

The Lake Victoria Basin (LVB) benefits from one of Africa's most advanced transboundary water-governance systems, anchored in the East African Community (EAC). A dense web of treaties, protocols, and standards provides a strong legal and policy basis for cooperation, though effectiveness remains constrained by incomplete ratification, uneven implementation, and limited national capacity.

5.7.1.1 Foundational Legal Instruments

Cooperation is anchored in key treaties and protocols that mandate basin-wide management, though their effectiveness depends on ratification and political will.

- **The EAC Treaty (1999)** establishes the constitutional basis for joint management of shared resources, mandating cooperation on transboundary pollution control, standards harmonisation, and information exchange.
- **Protocol for Sustainable Development of the Lake Victoria Basin (2003)** – operationalised the Lake Victoria Basin Commission (LVBC) and embedded core international water-law principles – equitable and reasonable use, no significant harm, precaution, and polluter-pays – while requiring environmental impact assessments and transboundary notifications.
- **Protocol on Environment and Natural Resources Management (2006)** – sought to consolidate EAC environmental law but has not entered into force, leaving a critical legal gap in basin-wide enforcement.

5.7.1.2 Strategies and Standards

Complementary instruments translate these mandates into strategic and technical guidance. The Draft EAC Water Policy (2022) advances integrated, pollution-preventive water management but awaits ministerial approval. The LVB Integrated Water Resources Management Strategy (2023–2050) provides a non-binding roadmap for rehabilitation, harmonised monitoring, and climate adaptation. Regionally adopted standards—the Industrial and Municipal Effluents Standard (2016) and Potable Water Specification (2017)—set binding discharge limits and drinking-water requirements. However, enforcement remains inconsistent across Partner States. **Table 5-9** summarises the status of key EAC legal and policy instruments relevant to water-quality management.

Table 5-9. Status of Key EAC Instruments Relevant to Water Quality Management

Instrument	Year	Key Provisions for Water Quality Management	Status	Ratification / Adoption
Treaty for the Establishment of the EAC	1999	Mandates cooperation on transboundary pollution control and harmonisation of standards; provides for creation of LVBC.	Binding	Ratified by all Partner States
Protocol for Sustainable Development of the LVB	2003	Establishes LVBC; enshrines equitable use, no-harm, precautionary and polluter-pays principles; requires EIAs and transboundary notification.	Binding	Ratified by Kenya, Rwanda, Tanzania, Uganda; acceded to by Burundi
Protocol on Environment and Natural Resources Management	2006	Comprehensive framework for WQM, pollution control, EIAs, and standards harmonisation.	Not in Force	Ratified by Kenya and Uganda; not ratified by Tanzania
Draft EAC Water Policy	2022	Promotes IWRM; sets provisions for water quality standards, pollution control, and ESIAs.	Draft (non-binding)	Adopted by Sectoral Council; final approval pending
LVB Integrated Water Resources Management Strategy	2023	Strategic actions for watershed management, pollution control, data sharing, and policy harmonisation (2023–2050).	Non-binding	Adopted as a guiding strategy
EAC Industrial & Municipal Effluents Standards	2016	Sets maximum permissible limits for pollutants in wastewater discharges.	Binding	Adopted regionally; implementation varies by Partner State
EAC Potable Water Specification	2017	Establishes minimum requirements for drinking water quality.	Binding	Domesticated by Kenya, Rwanda, Tanzania, Uganda

Source: *Synthesised from LVBC (2023), EAC (1999, 2003, 2006, 2022), and related policy documents.*

5.7.1.3 Regional Institutions

At the centre of implementation is the **LVBC**, mandated to promote and coordinate sustainable development in the Basin. It harmonises policies, mobilises finance, guides regional projects, and maintains basin-wide data systems. Its multi-tier structure—Council of Ministers, Coordination Committee, Sectoral Committees, and Secretariat—links political decision-making with technical execution, but effectiveness depends heavily on Partner State commitment and financing. Close coordination with the **Lake Victoria Fisheries Organization (LVFO)** is essential, given the interdependence between water quality and fisheries productivity.

5.7.1.4 Partnerships and Stakeholder Engagement

Regional governance has been strongly shaped by partnerships. The World Bank (LVEMP, CIWA, LWIS) and German cooperation (GIZ, KfW) have provided sustained financing, complemented by EU, UNEP, and FAO support for monitoring, fisheries, and sanitation. Collaboration with the Nile Basin Initiative strengthens data sharing, while national agencies and local governments engage in catchment rehabilitation and sanitation programmes that increasingly involve women, youth, and marginalised groups. However, dependence on external funding exposes monitoring and enforcement to interruption when donor cycles lapse, underscoring the need for sustainable, domestically anchored financing.

5.7.1.5 Implications of the Regional Framework

The governance framework demonstrates both institutional maturity and persistent fragility. The failure to operationalise the 2006 Protocol reflects tensions between national sovereignty and regional integration. Binding technical standards coexist with weak enforcement, creating a patchwork of partial compliance. Donor-driven priorities often outpace ecological realities, leaving implementation gaps at community level. Bridging these divides requires stronger political commitment, predictable financing, and governance mechanisms grounded in the socio-ecological conditions of the Lake Victoria Basin.

5.7.2 National Governance Frameworks

National water-quality governance in the Lake Victoria Basin operates under a principle of **coordinated sovereignty**: Partner States retain domestic control but commit to aligning laws and policies with EAC frameworks (EAC, 2003; LVBC, 2023). This balance allows flexibility but exposes systemic weaknesses – fragmented mandates, limited financing, and weak enforcement remain the greatest vulnerabilities of the basin framework.

5.7.2.1 National Policy and Legal Frameworks

Legal and policy maturity varies widely across Partner States. Kenya, Uganda, and Tanzania have comprehensive ***water and environmental legislation---Kenya's Water Act (2016)***, Uganda's *National Environment Act (2019)*, and *Tanzania's Water Resources Management Act (2009, amended 2022)* – yet enforcement is inconsistent, especially at local level. Uganda stands out with a dedicated *National Water Quality Management Strategy (2006)* and *Water Quality Management Framework (2017),* providing explicit operational guidance beyond general environmental laws. Rwanda has modern laws (mainly the Law *N°48/2018 on Environment and Law N°49/2018 Determining the use and Management Of Resources In Rwanda)* and strong political commitment but faces infrastructure challenges. Burundi, by contrast, relies on outdated statutes and dispersed responsibilities, leaving minimal regulatory capacity.

5.7.2.2 Absence of Basin-wide Water Quality Objectives and Management Targets

A critical weakness in the water quality governance framework of the Lake Victoria Basin is the absence of clearly defined, basin-wide water quality objectives for Lake Victoria and its tributaries. While Partner States have established effluent discharge standards and general environmental quality guidelines, these are largely input- and compliance-oriented and are not anchored to explicit ambient water quality targets or ecological status objectives for the lake, rivers, and sensitive bays. As a result, water quality monitoring generates extensive data without clear thresholds against which to assess ecological condition, management success, or regulatory adequacy. The lack of agreed objectives—such as target concentrations for nutrients, dissolved oxygen, chlorophyll-a, or cyanobacterial toxins—undermines the translation of scientific evidence into enforceable management actions, limits the ability to prioritise pollution hotspots, and weakens accountability for restoration outcomes. In the absence of such objectives, investments in wastewater treatment, catchment management, and wetland restoration remain fragmented and

difficult to evaluate in terms of their contribution to basin-wide recovery. Establishing harmonised, science-based water quality objectives is therefore a foundational requirement for shifting Lake Victoria management from reactive pollution control toward outcome-oriented, ecosystem-based governance

5.7.2.3 National Institutional Frameworks

Institutional arrangements reflect these disparities, ranging from relatively specialised models to fragmented ones.

- **Kenya and Rwanda** – Depend on semi-autonomous agencies with distinct mandates. In Kenya, the ***Water Resources Authority (WRA)*** regulates resources, while ***NEMA*** enforces environmental laws. In Rwanda, the ***Rwanda Water Board (RWB)*** oversees water resources, while ***REMA*** handles environmental protection. These enhance expertise but create overlaps—especially in Kenya, where coordination between national and county levels remains weak.
- **Uganda and Tanzania** – Employ integrated ministerial models. Uganda's ***Water Quality Management Department*** sits within the Ministry of Water and Environment, promoting coordination between water supply, resources, and environment. Tanzania's ***Water Quality Services Division*** works with Basin Water Boards and the ***National Environment Management Council (NEMC)***. These integrated approaches improve coordination but concentrate authority in ministries already stretched thin.
- **Burundi** – Marked by institutional fragmentation. Mandates are spread across ***MINEAGRIE, OBPE, INECN*** and others, resulting in duplication and weak accountability (LVBC, 2023).

Table 5-10 summarises national institutional arrangements and comparative strengths and weaknesses.

Table 5-10. Comparative Matrix of National Institutional Frameworks for Water Quality Management

Country	Lead Agency: Water Resources	Lead Agency: Environment	Utility Regulator	Key Strengths	Key Weaknesses
Burundi	DG for Environment, Water Resources & Sanitation (MINEAGRIE)	OBPE	AREEN	Formal mechanisms for coordination exist (e.g., CNCEA).	Highly fragmented mandates, outdated laws, weak labs, very limited staff.
Kenya	Water Resources Authority (WRA)	NEMA	WASREB	Strong legislation; established monitoring networks; mature private lab sector.	Weak enforcement; overlaps between agencies; uneven county-level capacity.
Rwanda	Rwanda Water Resources Board (RWB)	REMA	RURA	Modern laws, strong political will; clear institutional mandates; recent investment in modern laboratory for RWB.	Reliance on external labs; Limited wastewater regulation; capacity gaps.

Tanzania	MoW (Water Quality Service Division) & Basin Water Boards	NEMC	EWURA	Basin-level governance structures; accredited regional laboratories.	No national database; poor utility data integration; unclear stormwater mandates.
Uganda	MWE – Directorate of Water Resources Management	NEMA	MWE (Utility Regulation Dept.)	Integrated model; dedicated WQM Department; advanced tiered lab system.	Funding shortages; unclear sanitation regulation; unrealistic effluent standards.

Source: *Synthesized from LVBC (2023) and supplementary references.*

Cross-sectoral coordination mechanisms exist but remain uneven. Uganda's ***Kampala Pollution Control Task Force*** and Tanzania's national stakeholder forums show progress, yet most countries still operate in silos with poor data sharing. At the regional interface, National Focal Points coordinate with LVBC and LVFO but often lack the political leverage and resources to ensure commitments translate into action.

5.7.2.4 Enforcement Mechanisms and Compliance

The enforcement gap is one of the most critical weaknesses across all Partner States. While all countries have adopted formal discharge permits and effluent standards aligned with EAC guidelines, actual enforcement is sporadic due to limited staff, inadequate funding for field inspections, political interference, and weak penalties that fail to deter violations. Industrial facilities in Kenya and Uganda often bypass wastewater treatment, relying on dilution rather than compliance. Small and medium enterprises, particularly in peri-urban areas, rarely register or submit monitoring data. Agricultural non-point sources---responsible for much of the nutrient and pesticide loading---remain largely unregulated everywhere except in limited pilot zones.

Citizen science and community monitoring are emerging as partial solutions. Uganda's beach management units and Kenya's community water resource users associations provide local oversight, though their legal mandates are unclear and support is inconsistent.

5.7.2.5 Implications of National Frameworks

National systems show clear progress but also persistent weaknesses. Robust legal frameworks coexist with ongoing environmental degradation, largely due to weak local enforcement and political interference. Fragmented institutional mandates—most evident in Burundi—undermine accountability, while uneven adoption of EAC standards creates cross-border pollution risks. Addressing these gaps will require stronger national enforcement, sustainable financing, modern laboratory infrastructure, and integrated data systems capable of translating laws into measurable water-quality improvements.

5.7.3 Environmental Management Programs and Projects

Over the past three decades, riparian states of the Lake Victoria Basin (LVB), with strong international support, have mounted one of Africa's most ambitious responses to environmental decline. The approach has evolved from early knowledge generation to today's emphasis on large-scale infrastructure and integrated pollution control (Barghouti, 2006; World Bank, 2021).

5.7.3.1 Regional Coordinated Programs

The **Lake Victoria Environmental Management Project (LVEMP)** laid the foundation for coordinated action:

- **LVEMP I (1996–2005)** – Built the first basin-wide scientific knowledge base, set up monitoring protocols, and piloted community watershed projects and hyacinth control (LVEMP, 2005). It filled critical knowledge gaps at a time of very limited systematic data.
- **LVEMP II (2009–2017)** – Expanded to Rwanda and Burundi and shifted from data gathering to targeted interventions, focusing on pollution hotspots and degraded catchments, guided by a Transboundary Diagnostic Analysis (World Bank, 2018; **Figure 5-22**).
- **Lake Victoria Water and Sanitation Initiative (LVWATSAN I & II)** – Launched in 2004 under the EAC Water Ministers to accelerate progress toward the MDGs for water and sanitation in secondary towns across the Basin. Phase I (2004–2010) delivered infrastructure in 10 towns in Kenya, Uganda and Tanzania; Phase II (2011–2016) extended coverage to 15 towns including new sites in Rwanda and Burundi, with US$ 110 million in African Water Facility and AfDB grant financing. The initiative improved water and sanitation services for over 780,000 residents, strengthened local authority capacity, enhanced urban planning and solid-waste management, and reduced lake pollution from unserved secondary centres. Despite this progress, fewer than 10 percent of the Basin's ~250 secondary towns have been reached, leaving a large unmet investment need for future scaling.

Building on this sound foundation, current flagship programs are investment-focused and infrastructure-driven:



Figure 5-22. *A garbage collection truck belonging to the Kampala City Council Authority supplied under LVEMP II project still operational in 2025. (credit: Nicholas Azza)*

- **Lake Victoria Basin IWRM Programme (LVB IWRMP)** – Coordinated by LVBC with €38.9 million from Germany and the EU, it strengthens basin-wide IWRM, supports strategic planning, and finances four High Priority Investments (HPIs) in Kisumu, Mwanza, Kigali, and Kampala to upgrade wastewater and sludge management (KfW, 2019).

- **Lakewide Inclusive Sanitation (LWIS) Strategy** – Developed with the World Bank, this basin-wide roadmap addresses urban sanitation, stormwater, and solid waste—the dominant current sources of nutrient and organic pollution. It estimates $1.9 billion is required for sustainable sanitation, underscoring the gap between ambition and available resources (World Bank, 2021, 2025a).

5.7.3.2 Catchment Rehabilitation and Non-Point Source Control

Soil erosion and agricultural runoff are major drivers of nutrient and sediment pollution in the basin. Partner States and LVBC have prioritised catchment-level interventions, often financed through LVEMP and bilateral programmes.

- **Uganda's Sezibwa and Mpanga micro-catchments** – Integrated programmes combining soil conservation (terracing, agroforestry) with improved sanitation and erosion control reduced sediment loads by an estimated 25% and increased farmer incomes (WORLD BANK, 2018).
- **Kenya's Nyando River** – LVEMP and FAO supported community-led restoration of riparian zones, demonstrating reduced total suspended solids and higher dry-season flows, though gains proved vulnerable to extreme floods (2018, 2020).
- **Rwanda's buffer zone policy** – Legally mandated buffer strips (50 m from lakeshores, 10 m from rivers) have reduced direct nutrient input, but enforcement remains inconsistent in densely populated areas (LVBC, 2023).

Fertiliser use is accelerating in Rwanda and Uganda, yet extension services rarely include water-quality messaging, and precision nutrient management remains rare. No Partner State has successfully implemented the "polluter pays" principle for agricultural non-point sources, leaving diffuse loading largely unaddressed.

5.7.3.3 Urban Sanitation and Industrial Waste Management

The basin's urban centres – Kampala, Kisumu, Mwanza, Kigali – generate most of the point-source pollution but also drive the most visible progress.

- **Sewerage upgrades**
  - *Kampala (Uganda):* Bugolobi and Lubigi wastewater treatment plants now serve 250,000 and 150,000 people respectively, though collection rates lag.
  - *Kisumu (Kenya):* LVEMP III interventions aim to increase treatment coverage from 20% to 40% through upgrades to Kisat and Nyalenda plants and a new facility at Otonglo.
  - *Mwanza (Tanzania):* A €150 million project built the Butimba water plant (serving 450,000 people) and extended simplified sewers to 150,000 residents in informal areas.
  - *Kampala (Uganda):* The updated Drainage Master Plan improves stormwater management, a major urban pollution pathway.
- **Industrial effluents** – LVEMP pilots in Uganda showcased low-cost wetland systems for treating brewery effluents at Port Bell, with potential for replication in other industrial zones.
- **Solid waste** – Kisumu County pioneered circular economy models through community-run material recovery facilities that reduce dumping, create jobs, and reclaim recyclables.
- **Plastic pollution** – Microplastics are now found in all sampled lake sites and in about 20% of commercial fish species, signalling an emerging ecological and food-safety risk (Biginagwa et al., 2016; The Flipflopi, 2024).

- **Rural sanitation** – Community-based programs---such as Uganda's Mukono partnerships and Tanzania's culturally adapted outreach in fishing communities---show that locally tailored models can succeed where conventional sewerage is unfeasible.
- **Emergency preparedness** – A major gap persists: despite the rapid growth in petroleum and chemical transport across the Lake Victoria Basin, the region lacks a basin-wide oil-spill preparedness and response system. Essential spill-containment and clean-up equipment is largely unavailable or insufficient, and budgetary allocations for disaster risk reduction remain low. Together, these gaps severely constrain preparedness, training, and rapid response, leaving the lake's sensitive ecosystems and dependent communities highly vulnerable to accidental spills and their environmental and public-health consequences (LVBC, 2024).

Despite these interventions, coverage remains far from adequate. An estimated 70--80% of urban wastewater still enters the lake untreated. Industrial compliance is poor, and informal settlements continue to expand without basic sanitation. Meeting SDG 6 (clean water and sanitation) by 2030 would require investments exceeding US$1.9 billion – far beyond current funding levels.

5.7.4 Water Quality Monitoring, Laboratory Services and Data Management Systems

Effective management of Lake Victoria's water resources depends on a coordinated monitoring system that generates reliable and comparable evidence across countries. For years, monitoring was fragmented and under-resourced, resulting in data gaps and weakened confidence in assessments. The recent revival of regional cooperation under LVBC—linking field networks, laboratories, and data platforms—marks a turning point toward credible, evidence-based basin management. This section reviews the renewed monitoring networks, analytical capacity, and data-management systems that now underpin the basin's water-quality governance framework.

5.7.4.1 Transboundary and National Monitoring Networks

The Lake Victoria Basin hosts an extensive but unevenly developed network of water quality monitoring stations coordinated through national agencies and the Lake Victoria Basin Commission (LVBC). The harmonised regional framework, originally established under LVEMP-1, defines 98 transboundary stations strategically distributed across rivers, wetlands, and lake zones. It provides the backbone for regional coordination and serves as a reference for Partner States' national networks. Despite operational interruptions over the past two decades, the framework remains central to aligning methodologies, parameters, and data standards across countries.

At the national level, the density and performance of monitoring systems vary widely:

- **Kenya** – Operates 223 surface water quality monitoring stations (including 136 within the Lake Victoria catchments), some equipped with real-time telemetry. However, monitoring coverage has declined, and consistency is constrained by equipment failure (notably broken multiprobes) and shortages of consumables.
- **Uganda** – Maintains 119 national water quality monitoring sites in addition to 10 transboundary stations. The National Water and Sewerage Corporation (NWSC's) operates 75 laboratories which collectively analyze ~120,000 water and 6,000 wastewater samples annually. Despite this strong capacity, 40% of monitoring sites are inactive due to persistent budgetary shortfalls.
- **Tanzania** – operates LVEMP-1 era monitoring networks covering industrial effluents, municipal wastewater, and catchments around Mwanza, Bukoba, and Musoma.

While laboratories responsible for monitoring the lake in the three regions above are accredited, sampling is irregular and monitored parameters are limited in scope.

- **Rwanda** – Runs 72 monitoring stations across Nile River basin catchments. Monitoring covers nutrients, BOD5/COD, turbidity, and bacteria, but capacity for monitoring agrochemicals and metals remains limited or absent.
- **Burundi** – Currently lacks a fully functional national water quality monitoring network. Existing monitoring depends on a few hand-held probes with no systematic sediment sampling capacity. Plans to link new sites to hydromet stations remain unrealised.

The harmonized monitoring framework across Tanzania, Kenya, and Uganda marks a major step toward coordinated management of the Lake Victoria Basin. Achieving full basin-wide monitoring will require expansion of coordinated operations to Rwanda and Burundi, sustained institutional capacity, stable financing, and broader parameter coverage.

5.7.4.2 Analytical and Technological Capacity

The Lake Victoria Basin's capacity to monitor water quality has advanced markedly in recent years, driven by substantial investment in laboratory infrastructure, data management systems, and modern sensing technologies. Across the Partner States, numerous laboratories have been upgraded with modern analytical equipment, several expanded, accredited, and adequately resourced, and Laboratory Data Management Systems (LDMS) established to improve data handling, storage, and retrieval. These developments have enhanced the credibility, traceability, and comparability of water quality data across the basin. Nevertheless, progress remains uneven, with persistent gaps in technical expertise, maintenance capacity, and operational financing limiting the full realization of these gains.

Laboratory Systems

Laboratory capacity forms the backbone of credible water-quality monitoring but continues to vary widely among Partner States, largely reflecting national institutional and financing arrangements (see Section 5.7.2).

- **Uganda** hosts the region's most advanced network—a three-tier system anchored by the National Water Quality Reference Laboratory in Entebbe, supported by four regional facilities and 75 utility laboratories under NWSC. These laboratories, equipped with GC-MS, HPLC, and LC-MS systems (see **Figure 5-23**), analyse over 30 parameters and have integrated LDMS platforms for quality control and data storage. However, unreliable power supply and limited maintenance contracts remain operational challenges.
- **Kenya** combines public laboratories in Kisumu and Kakamega with a strong private sector. The Kisumu facility undertakes extensive chemical and microbiological analyses, while accredited private laboratories such as **SGS** and **Crop Nuts** provide high-end contaminant and residue testing. The establishment of a centralized LDMS has strengthened data traceability, though sustained funding and calibration support are still needed (see **Figure 5-24**).
- **Tanzania** operates four accredited Basin laboratories, including the ISO 17025–certified Mwanza Laboratory, which is capable of advanced physico-chemical analyses. Recent equipment upgrades have improved analytical precision, but the reliance on external technicians for servicing and calibration causes costly operational delays.
- **Rwanda** has made progress in upgrading university-based testing capacity and plans to establish mobile and central laboratories. However, the absence of a dedicated national facility still limits the ability to test for heavy metals and agrochemicals, constraining comprehensive water quality surveillance.

- **Burundi** remains the weakest link in the regional network, with only two under-resourced institutions—**INB and IGEBU**—that possess limited analytical and data management capacity. External support will be essential to achieve minimum basin-wide analytical standards.

Technological Innovations

Parallel to laboratory upgrades, the Partner States are increasingly embracing digital and remote-sensing innovations. Wireless Sensor Networks (WSNs) are being deployed to provide near-real-time measurements of pH, conductivity, turbidity, and temperature, enabling early pollution alerts and reducing the frequency of manual field sampling. However, high maintenance costs and inconsistent connectivity continue to impede continuous operation.

Collaborations with the European Space Agency and the World Bank have introduced satellite-based tools that track chlorophyll-a, turbidity, and algal blooms, providing synoptic lake-wide monitoring. When combined with improved ground-based calibration, these technologies significantly enhance the spatial and temporal resolution of water quality assessment.

To sustain this progress, Partner States need to harmonize analytical standards, ensure predictable financing for equipment maintenance, and integrate laboratory and sensor data through interoperable data platforms. Strengthening national LDMS and linking them to a regional Lake Victoria Basin Water Information System (LVB-WIS) would further consolidate the gains made and enhance transboundary data comparability and transparency.

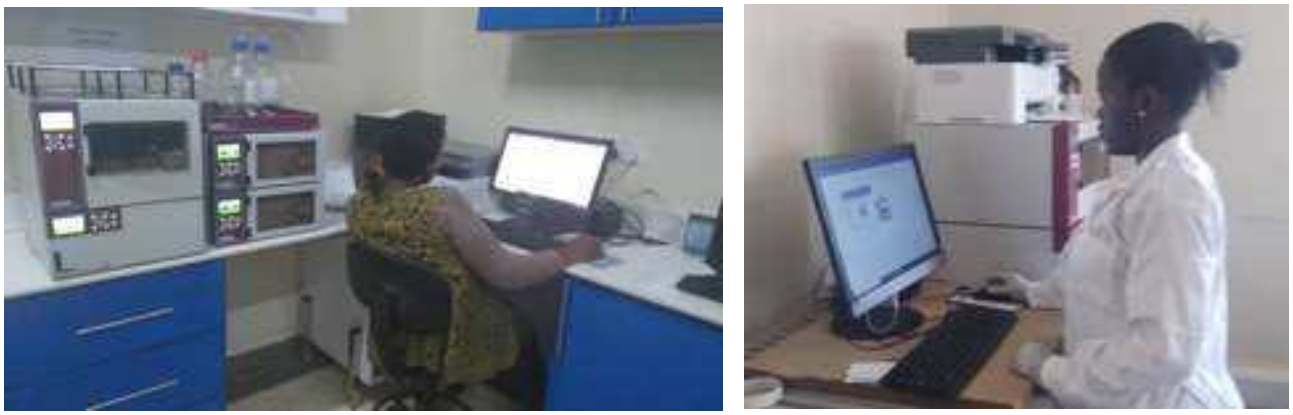


Figure 5-23. *Staff of the National Water Quality Reference Laboratory in Entebbe, Uganda carrying out water tests.*



Figure 5-24. *An analyst in the WRA water quality laboratory in Nairobi. (Water Resources Authority, Kenya).*

5.7.4.3 Regional Research Assets

The **Research Vessel (RV)** ***Jumuiya*** (see **Figure 5-23**), managed by the Lake Victoria Basin Commission (LVBC), is the basin's only regional offshore limnological platform. After over a decade of inactivity (2012–2023) due to mechanical and certification challenges, it was rehabilitated with US $118,000 and relaunched in 2023—marking a major step in restoring deep-water monitoring and regional scientific collaboration.

The vessel has revived joint lake cruises involving Kenya, Tanzania, and Uganda, and played a central role in the 2025 basin-wide monitoring campaign, the first in more than two decades. Covering 44 of the 98 harmonized LVEMP-1 stations, the mission produced a unified dataset for the ***State of the Basin Report 2025*** (GIZ, 2025b) and reinvigorated cooperative science governance.

By standardising sampling protocols and analytical methods, the RV ***Jumuiya*** enhances data comparability, supports early pollution detection, and strengthens joint accountability for Lake Victoria's health. It now anchors a shift from fragmented, project-based efforts to a coordinated, basin-wide monitoring framework—critical for sustaining evidence-based management, scientific continuity, and informed policy decisions across the region.



Figure 5-25. *The Research Vessel Jumuiya during the joint lake cruise in June-July 2025.*

5.7.4.4 Data Management and Sharing

Data collection is only the first step; effective management, sharing, and application are equally critical. In the Lake Victoria Basin, information remains fragmented—held in incompatible formats and seldom shared across borders. Although earlier LVEMP databases demonstrated that integrated systems are feasible, they were never institutionalized, leaving decision-making hindered by persistent data gaps.

Regional platforms

- **LVB-WIS (2024)** – Developed under the IWRM Programme with German/EU support, this centralised hub integrates hydrological and water quality datasets, GIS mapping, IWRM models, and key publications. Its usefulness depends on consistent national data uploads, which remain patchy.
- **Lake Victoria Monitoring Portal** – Led by UKCEH and KMFRI, consolidates monitoring and research data for public access. It enhances transparency but does not replace a formal intergovernmental data-sharing mechanism.

National systems

As noted in Section 5.7.2, national institutional frameworks influence data management capacity and governance. The current landscape shows:

- **Kenya** operates two advanced systems (MIKE INFO and LIMS) capable of time series analysis, GIS mapping, and real-time data uploads. Yet integration between the systems is incomplete, and datasets remain fragmented across institutions.
- **Rwanda** uses AQUARIUS software managed by RWB, with a public web portal offering statistics, time series plots, and site mapping. WASAC maintains a separate database for drinking water abstraction points.
- **Uganda** has developed a modern database as part of the Water and Environment Information System (WEIS) (**Figure 5-26**). NWSC operates its own LIMS for Kampala, but these systems are not linked, reflecting the broader challenge of institutional coordination discussed in Section 5.7.2.2.
- **Tanzania** has developed a Laboratory Information Management System mostly used for data archiving. The Lake Victoria Basin Water Board produces periodic state of environment and state of water reports.
- **Burundi** lacks a centralised system, with limited data scattered across small institutional databases. Inconsistencies in methods and formats make aggregation difficult.



Figure 5-26. *Uganda's new water quality data management system showing Lab Manager dashboard.*

Data access rules vary. Rwanda offers relatively open access; Uganda and others require clearance from senior officials. Some institutions link to global platforms (e.g., GEMS Water), but no binding regional protocol exists.

Despite significant technical advances, a persistent "last-mile" problem continues to undermine effective water-quality management. Databases are inconsistently updated, institutional coordination remains weak, and monitoring standards and procedures differ across countries. Most critically, the absence of a binding regional data-sharing framework prevents the seamless exchange of information needed for timely, basin-wide decision-making. Closing these gaps is essential: without consistent and timely information exchange, even well-funded monitoring networks and laboratories cannot produce the integrated insights required for sound governance of the Lake Victoria Basin.

5.7.5 Citizen Science Application in Water Quality and Pollution Control in the Lake Victoria Basin

5.7.5.1 Bridging the Basin's Monitoring Gap: The Rise of Citizen Science in the LVB

The Knowledge Vacuum

Lake Victoria is under accelerating pressure from population growth, land-use change, and intensifying economic activity, driving eutrophication, biodiversity loss, and rising public health risks with clearly transboundary consequences (World Bank, 2022; Verschuren et al., 2002). Effective response to these threats depends on high-quality, continuous, and spatially resolved data. Yet state-led monitoring systems across the basin remain structurally inadequate.

Environmental agencies in Kenya, Uganda, and Tanzania operate under chronic financial and logistical constraints that severely limit sampling frequency and spatial coverage (Gemmell, 2021; Hutchings & Willcock, 2022). Monitoring networks are widely spaced across the 68,800

km² lake, making them incapable of detecting localized pollution hotspots or rapidly evolving nearshore risks (Mzava et al., 2020; WWQA, 2021). Even when data is collected, it is often locked within specific institutional silos or academic reports, inaccessible to local communities or transboundary partners (Gemmell, 2021).

This combination of spatial sparsity, temporal discontinuity, and restricted data access has created a widening gap between the basin's escalating information needs and the capacity of formal institutions to supply them. It is within this structural knowledge vacuum that citizen science has shifted from a supplementary activity to a strategic pillar of basin-wide monitoring—expanding data coverage, accelerating feedback loops, and partially compensating for institutional monitoring deficits (Stenfert Kroese et al., 2021; Nthiga, 2024).

Defining Citizen Science in the LVB Context

Citizen Science (CS) is the participatory involvement of non-professional volunteers in the generation of scientific knowledge. In the Lake Victoria Basin, citizen science (CS) spans a continuum from contributory models—where communities collect data for scientific analysis—to co-created models in which citizens jointly define research questions and apply findings for local decision-making and advocacy (Stenfert Kroese et al., 2021). In practice, CS is closely linked to community-based natural resource management, reflecting the principle that resource-dependent communities are both highly motivated and strategically positioned to monitor ecosystem health.

The regional growth of CS has been driven by two reinforcing transformations. First, the rapid diffusion of smartphones and low-cost environmental sensors has reduced technical and financial barriers to reliable local data collection (Mzava et al., 2020). Second, governance decentralization in countries such as Uganda and Kenya has devolved environmental management responsibilities to sub-national authorities, creating a formal demand for locally generated environmental data (Oosterveer & Van Vliet, 2010).

The "Triangulation" Paradigm

The leading framework guiding contemporary citizen science in the basin is the triangulation approach, which integrates in situ measurements, Earth observation, and water-quality modeling into a single validation system (WWQA, 2021). Within this framework, citizen data provide essential ground truth, bridging the scale gap between localized field conditions, satellite observations, and basin-wide models. This strengthens the accuracy, credibility, and policy relevance of integrated monitoring systems (Gemmell, 2021).

5.7.5.2 Extent of Application: Country-Specific Patterns

The application of citizen science across the Lake Victoria Basin varies markedly by country, reflecting differences in governance structures, legal frameworks, technological capacity, and environmental priorities.

Kenya: Methodological and Institutional Leader

Kenya has emerged as the regional innovator, benefiting from a relatively open civic space and strong links to international research networks. A landmark example is the **Citizen-based Index of Ecological Integrity (CIEI)** developed in the Nzoia, Yala, Sondu-Miriu, and Kuja river systems. By combining macroinvertebrate observations with community knowledge, the CIEI demonstrated that citizens can reliably detect gradients of ecological disturbance comparable to professional biomonitoring, with northern rivers showing significantly higher degradation due to agriculture and urbanization (Aura et al., 2020).

Kenya has also institutionalized citizen monitoring through **Participatory Environmental Monitoring (PEM) Guidelines**, grounded in constitutional public participation and environmental law. These guidelines formally recognize citizen-generated data as procedurally valid for environmental oversight, particularly in

water and extractive sectors (NEMA, 2025).

In the **Winam Gulf**, citizen nutrient sampling using the FreshWater Watch platform is integrated with satellite products under the World Water Quality Alliance's triangulation framework. This has revealed the Gulf's role as a pollutant sink with limited flushing, directly informing local eutrophication management and aquaculture regulation (Gemmell, 2021; WWQA, 2023).

Tanzania: Legal Admissibility and Transboundary Enforcement

Tanzania's model is distinguished by the legal enforceability of digitally generated citizen data. Under the Electronic Transactions Act (2015) and supporting evidence law, geo-tagged and time-stamped citizen observations are, in principle, admissible in court, subject to data integrity standards (Makulilo, 2016).

In the Mara River Basin, communities monitor nutrients using standardized FreshWater Watch protocols to track pollution arising from upstream agriculture and downstream mining. These data have been used to identify point-source contamination from gold mining operations, supporting regulatory enforcement by the National Environment Management Council (Nthiga, 2024; WWQA, 2023).

Although outside the LVB, Tanzania's Rufiji e-flows programme demonstrates how community monitoring can influence formal water allocation and is now informing adaptation of similar approaches in the Simiyu catchment (GEF, 2020).

Uganda: Decentralization and Co-Management

Uganda's citizen science landscape is shaped by deep administrative decentralization. Beach Management Units (BMUs)—legally established fisheries co-management bodies—are increasingly being mobilized as frontline environmental sentinels, particularly for detecting fish kills linked to hypoxia and algal blooms (LVFO, 2024). However, their role remains constrained by limited access to sensors and laboratory capacity, relying heavily on visual and experiential indicators (Nthiga, 2024).

In the Entebbe–Jinja urban–industrial corridor, NGO-led citizen science initiatives focus primarily on WASH-related indicators in highly polluted nearshore zones (Hutchings & Willcock, 2022). Uganda is now strengthening a hybrid monitoring architecture by integrating new automated water-quality stations supplied by the Nile Basin Initiative with community-based reporting systems (NBI, 2025b).

Rwanda and Burundi: Biodiversity-Linked Monitoring

In Rwanda and Burundi, citizen science is most strongly linked to biodiversity conservation and landscape restoration rather than direct chemical monitoring. In Rwanda, youth-based programmes under the Living Lakes and ARCOS initiatives—often referred to as "Future Lake Managers"—track wetland condition and waterbird populations as indirect indicators of aquatic ecosystem health (Living Lakes, 2024; University of Rwanda, 2022). These bio-indicator approaches are formally aligned with national urban restoration and nature-based solutions programmes (IISD, 2025).

In Burundi, citizen engagement remains largely embedded in community-based natural resource management (CBNRM) structures around Kibira and Ruzizi protected areas. Local committees monitor water sources and infrastructure integrity and act as the first line of reporting for contamination events in areas with weak state presence (UNDP, 2022).

5.7.5.3 Technology and Data Integration

The transformation of citizen science from a peripheral activity into a functional governance instrument has been driven by rapid technological convergence. Paper-based reporting has been largely replaced by interoperable digital platforms, mobile applications, and automated analytics that allow citizen data to enter formal monitoring systems in near real time.

The GlobeWQ Integration Platform

The GlobeWQ platform now represents the core data-integration infrastructure for the Lake

Victoria Basin. It functions as a clearinghouse that combines citizen-generated observations, satellite products, and professional monitoring records into a single operational environment. The platform enables users to upload citizen CSV datasets and directly compare them with GEMStat global water-quality records, lowering technical and institutional barriers to data access and visualization (Gemmell, 2021).

Through its modeling interface, GlobeWQ also addresses spatial discontinuities in monitoring. For example, citizen measurements at river mouths can be combined with satellite observations of the open lake to simulate pollutant plume dispersion and mixing dynamics, strengthening basin-scale diagnostics (WWQA, 2021).

Mobile Applications and Standardized Methods

Standardized mobile applications have been critical for ensuring data consistency and auditability. FreshWater Watch, widely used in Kenya and Tanzania, requires users to undertake basic chemical tests for nitrates and phosphates, with automatic geo-tagging and time-stamping of results to create verifiable digital records (WWQA, 2023). EyeOnWater, based on smartphone colorimetry using the Forel–Ule scale, provides a rapid proxy for turbidity and algal biomass and is particularly valuable for validating satellite algorithms in Lake Victoria's optically complex waters (Gemmell, 2021).

Data Validation and Quality Assurance

Concerns over the reliability of citizen-generated data have been addressed through rigorous regional validation studies. In the Kenyan catchments, suspended sediment concentrations measured by citizen scientists were shown to correlate extremely strongly with automated gauging stations ($R^2 > 0.9$), demonstrating that low-cost methods can achieve professional-level accuracy for selected parameters (Stenfert Kroese et al., 2021). Independent bio-monitoring validation using the Citizen-based Index of Ecological Integrity (CIEI) further confirmed that community assessments of river health closely align with professional ecological surveys (Aura et al., 2020).

Together, these digital platforms, standardized tools, and empirical validation results form the technical backbone that enables citizen science to transition from experimental monitoring into a credible, scalable component of basin-wide environmental governance.

5.7.5.4 Strengthening and Mainstreaming

For citizen science (CS) to mature from donor-driven experimentation into a permanent feature of basin governance, it must be embedded in legal systems, institutional mandates, and national reporting architectures.

Legal Mainstreaming

The decisive frontier for mainstreaming CS is the legal admissibility of citizen-generated data. Tanzania currently offers the strongest legal foundation through its Electronic Transactions Act (2015), which explicitly recognizes digital evidence subject to proof of authenticity and integrity (United Republic of Tanzania, 2015). Kenya's constitutional guarantees of public participation, reinforced by formal Participatory Environmental Monitoring (PEM) Guidelines, provide a robust administrative pathway for enforcement, even where judicial precedent remains limited (NEMA, 2025). Uganda and Rwanda permit digital evidence in principle, but weak judicial capacity and limited case law constrain practical application.

Across all jurisdictions, the central technical requirement is the establishment of a secure digital chain of custody. Citizen science platforms must lock metadata, encrypt data at capture, and maintain full audit trails to ensure that records are tamper-proof and admissible for regulatory and judicial use.

Institutional Mainstreaming

At basin scale, regional institutions provide the most direct pathway for formal integration. The Lake Victoria Basin Commission (LVBC) is best positioned to issue a regional citizen science standard, ensuring that measurements collected

in different countries are methodologically comparable and interoperable within the Lake Victoria Basin Water Information System (Nthiga, 2024). Embedding accredited CS data directly into the LVB-WIS would allow citizen observations to contribute systematically to future State of the Basin reporting.

The Lake Victoria Fisheries Organization (LVFO) manages over 1,000 Beach Management Units (BMUs), representing an unmatched monitoring network. Formal expansion of the BMU mandate to include basic water-quality surveillance—supported by minimal equipment such as Secchi tubes and pH kits—would instantly create the densest lake monitoring system in Africa (LVFO, 2024).

At the Nile scale, the Nile Basin Initiative (NBI) is already operationalizing CS through its macroplastic monitoring action plan, which relies explicitly on trained citizen monitors to generate standardized data capable of informing basin-wide plastic control policies (NBI, 2025a).

Integration into SDG Reporting

A powerful incentive for governments to adopt CS lies in the reporting requirements of SDG 6.3.2 on ambient water quality. Countries such as Sierra Leone and Zambia have successfully incorporated validated citizen data into official SDG submissions, strengthening national datasets and international credibility (GEMStat, 2024). Replicating this model in the Lake Victoria Basin would allow CS data to contribute to global reporting, enhance transparency, and improve access to climate and environmental finance.

5.7.5.5 Challenges and Barriers

Despite a clear institutional pathway, three structural barriers remain dominant. Institutional inertia persists, with regulators often viewing citizen data as inferior to state-generated records; overcoming this requires sustained co-design of protocols and continuous validation (Nthiga, 2024). Financial sustainability is weak, as many CS initiatives collapse once donor funding ends; long-term viability depends on integrating CS costs into district budgets, BMU levies, or routine agency operations (Nthiga, 2024). Finally, the digital divide risks excluding poorer and rural communities—especially women—from app-based monitoring, despite their central role in water stewardship (Nthiga, 2024).

5.7.5.6 Conclusion and Strategic Recommendations

The Lake Victoria Basin has entered a phase where environmental pressures now exceed the response capacity of conventional state-led monitoring systems. Citizen science offers a scalable 21st-century complement—mobilizing millions of basin residents as real-time environmental sentinels while strengthening the evidence base for governance.

To mainstream this potential, four strategic priorities emerge:

1. **Regional Standardization:** The LVBC should adopt a formal regional protocol on community-based monitoring to harmonize methods, data formats, and quality standards across Partner States.
2. **Legal Readiness by Design:** Citizen science applications must integrate digital chain-of-custody protections—including metadata locking and encryption—to ensure that community data is legally admissible in regulatory and judicial processes.
3. **National Accreditation Systems:** Environmental authorities should establish certification frameworks through which accredited citizen groups feed directly into national databases for SDG reporting and pollution hotspot detection.

By aligning community participation with digital monitoring systems and enforceable legal frameworks, the Lake Victoria Basin can transition from fragmented surveillance to a globally exemplary model of participatory environmental governance.

5.7.6 Key Challenges and Strategic Recommendations

After two decades of regional cooperation, the Lake Victoria Basin has developed strong institutional frameworks for water quality management. However, ecological degradation persists due to weak enforcement, limited financing, and uneven technical capacity.

5.7.6.1 Key Challenges

1. **Governance and Enforcement Deficit:** Policies and protocols are well crafted but poorly implemented. Delays in ratifying the *EAC Protocol on Environment and Natural Resources* and approving the *EAC Water Policy* (2022) highlight sovereignty–integration tensions. Fragmented mandates (e.g. Burundi's MINEAGRIE, OBPE, INECN) and overlapping roles (WRA–NEMA, RWB–REMA) weaken accountability, while local governments remain under-resourced to enforce regulations.
2. **Capacity and Technical Gaps:** Laboratories and monitoring infrastructure remain underused due to limited funding for operations, reagents, and maintenance. Few mobile labs and research vessels constrain monitoring. Uganda is the only counry with its own offshore research vessel **(Figure 5-27).** Analytical capacity varies widely across countries, and most laboratories lack advanced equipment or inter-laboratory calibration. Emerging contaminants such as pesticides, pharmaceuticals, and microplastics are rarely assessed.
3. **Fragmentation and Weak Harmonisation**: Water-quality standards, protocols, and data systems differ across Partner States. The LVB-WIS is underutilised without a binding data-sharing framework. This inconsistency hinders basin-wide analysis and coordinated responses.
4. **Financial Constraints and Donor Dependency:** Recurrent costs for monitoring and enforcement are chronically underfunded, leaving programmes donor-dependent and vulnerable to funding cycles. Domestic financing mechanisms—pollution levies, cost recovery, or ecosystem-payment schemes—remain weak. Current investments meet only a fraction of the estimated US$1.9 billion basin sanitation need.



Figure 5-27. *The MV IMB (Inner Murchison Bay) – a new offshore research vessel of Water Quality Management Department of Uganda. (Credits: MoWE, Uganda).*

5.7.6.2 Strategic Recommendations

The following recommendations, which address the above challenges, build on ongoing regional initiatives under LVBC and EAC frameworks and aim to ensure sustainable and coordinated management of shared water resources.

- **Policy and Governance**
  - Finalize and ratify key instruments – including Protocol on Environment and Natural Resources Management, and EAC Water Policy, to strengthen the legal and institutional coherence of transboundary water governance.
  - Adopt regionally harmonized water quality objectives for Lake Victoria and transboundary river systems of the Lake Victoria Basin.
  - Shift emphasis from policy drafting to enforcement and regulatory compliance by resourcing regulatory agencies and applying the polluter-pays principle consistently.
  - Consolidate mandates in countries with fragmented institutional frameworks, such as Burundi, by designating a clear lead agency for water quality management and streamlining responsibilities amongst related agencies.
  - Establish a LVB Water Quality Coordination Committee under the LVBC and strengthen coordination between national environment and water agencies and the LVBC.
- **Institutional and Decentralised Action**
  - Strengthen basin and catchment offices with adequate budgets, vehicles, laboratory equipment and legal powers for local monitoring and enforcement.
  - Create national cross-sectoral coordination platforms to link water, environment, agriculture, health, industry and finance sectors, build synergies amongst them and minimize duplication. Formalized inter-agency collaboration through MoUs.
  - Require mandatory water-quality impact assessments for large-scale agricultural, industrial, mining, and urban initiatives.
- **Capacity and Harmonisation**
  - Establish regional centres of excellence: one for laboratory calibration, accreditation, and repair; another for advanced training and remote sensing.
  - Resume regular joint lake-wide water quality sampling and analysis.
  - Adopt a harmonised regional monitoring manual, promote networking of laboratories in the basin, and strengthen inter-laboratory comparison and quality assurance.
  - Enhance data integration and interoperability across national databases, ensuring real time exchange with the LVB-WIS for improved transparency and region decision making
  - Strengthen science–policy linkages so that findings from joint monitoring and LVB-WIS outputs directly inform policy formulation, investment planning and regulatory enforcement.
  - Develop a basin-wide strategy for agricultural non-point pollution to scale sustainable land management.
- **Financing and Investment Mechanisms**
  - Mainstreaming transboundary water management into national planning and budgeting cycles to institutionalize long-term commitment and ownership by Partner States
  - Stabilise recurrent funding for monitoring and enforcement at both LVBC and national levels.
  - Broaden financing through green and blue bonds, climate and results-based finance, and payments for ecosystem services.
  - Enforce a comprehensive polluter-pays regime to internalise environmental costs.
  - Establish a Lake Victoria Basin Water Quality Trust Fund—a US$100 million endowment jointly capitalised by governments, development partners, and private sector—to finance long-term monitoring, innovation, and restoration.
  - Encourage private-sector participation in circular economy models for waste and wastewater reuse.

- **Technical Infrastructure**
  - Modernise laboratories through new buildings (Figure 5-28) and coordinated procurement of analytical equipment and reagents, supported by a regional maintenance and calibration centre.
  - Expand field capability with mobile laboratories and construct RV Jumuiya II for basin-wide water quality surveys.
  - Strengthen public access to environmental information through open-data dashboards, annual basin reports, and tailored communication tools designed for policymakers, practitioners, and community stakeholders.
  - Support citizen-science initiatives that engage local communities in water-quality monitoring, pollution tracking, and mobile data reporting, fostering inclusivity, awareness, and shared stewardship of basin resources.

5.7.6.3 Way Forward

Closing the gap between regional ambition and national execution demands stronger enforcement, stable financing, and empowered institutions. By anchoring governance in sustained domestic investment and shared accountability, the Basin can move from policy to tangible results—ensuring a cleaner, healthier, and more resilient Lake Victoria for future generations.



Figure 5-28. *A new office block under construction in Entebbe to accommodate Uganda's National Water Quality Reference Laboratory. (credits Nicholas Azza).*

5.8 Future Outlook and Recommendations

This section looks ahead to the basin's plausible futures and the choices that will shape them. It synthesises the evidence to outline two trajectories—**Business as Usual** versus **Sustainable Investment & Cooperation**—and the drivers that will push the lake one way or the other. It then distils the principal gaps that currently blunt progress and sets out a practical, five-pillar agenda to strengthen the evidence base, harmonise and enforce rules, mobilise sustainable finance, reduce both point- and non-point-source pollution, and build climate-resilient, community-backed solutions.

5.8.1 Projected Trends and Scenarios

5.8.1.1 Future Pathways for Water Quality in the Lake Victoria Basin

The future of the lake will be determined by how decisively the region responds to two main drivers of change:

- **Population growth and urbanisation.** The basin's 45 million-plus people and fast-growing towns are driving soaring water demand and waste generation. Without major sanitation and waste-management investments, untreated sewage, solid waste, and agricultural runoff will further degrade water quality (World Bank, 2025a, 2025b).
- **Climate change.** Intensifying floods, droughts, and heatwaves will accelerate eutrophication, expand oxygen-depleted "dead zones," and heighten health and migration pressures (Odhengo et al., 2022; World Bank, 2021).

To illustrate possible futures, two scenarios are presented below.

- **Scenario 1 – Business as Usual (BAU):** If current investment and enforcement levels persist, population growth and climate pressures will continue to outpace response capacity. Pollution from untreated sewage, solid waste, and agricultural runoff will intensify, accelerating eutrophication, algal blooms, and oxygen-depleted zones. Declining water quality will trigger fisheries collapse, food insecurity, and recurrent disease outbreaks such as cholera and typhoid, deepening poverty and resource conflicts around fishing grounds. The basin risks becoming locked in a cycle of environmental degradation and socio-economic decline.
- **Scenario 2 – Targeted Interventions & Incremental Progress (middle path):** This pathway focuses on strategic "islands of success." Concentrated investments in major urban hubs and high-value industries lead to localized improvements in wastewater treatment and regulatory compliance. However, these gains are offset by rapid growth in secondary towns and informal settlements where infrastructure remains stagnant. While these targeted actions successfully slow the rate of ecological decline and prevent total fisheries collapse, the lack of basin-wide targets and uniform enforcement leaves many areas vulnerable. The result is a state of "managed degradation" where water quality persists as a chronic challenge
- **Scenario 3 – Sustainable Investment & Cooperation:** With strong political commitment, predictable finance, and coordinated implementation of basin

programmes such as the ***Lakewide Inclusive Sanitation (LWIS) Strategy*** and ***LVB-IWRM Programme***, pollution from cities and farms would decline, wetlands and ecosystems recover, and fish stocks stabilise. Improved sanitation and waste-management infrastructure would reduce health risks, while investments in watershed restoration, renewable energy, and circular-economy models (e.g., water reuse, waste-to-energy) would foster green jobs and climate resilience. This cooperative pathway offers a credible route to restoring water quality, protecting livelihoods, and securing the lake's long-term sustainability.

5.8.1.2 Water Quality Objectives

A central priority for reversing water quality decline in the Lake Victoria Basin is the establishment of harmonised, basin-wide water quality objectives that translate scientific evidence into clear management outcomes. These objectives should define desired ambient conditions for Lake Victoria and its major tributaries, differentiated by ecological setting—offshore waters, nearshore zones, semi-enclosed bays and gulfs, and inflowing rivers—and expressed through measurable indicators such as nutrient concentrations, dissolved oxygen thresholds, chlorophyll-a levels, and limits for cyanobacterial toxins and priority pollutants.

Anchoring monitoring, regulation, and investment decisions to agreed objectives would enable Partner States and LVBC to move from descriptive assessments toward outcome-based management, strengthen enforcement of effluent controls, prioritise hotspots for intervention, and systematically evaluate the effectiveness of wastewater treatment, catchment restoration, and wetland protection measures. Developing these objectives through a phased, science-based and consultative process—aligned with national standards and regional commitments—would provide a unifying framework for coordinated action and long-term recovery of Lake Victoria's water quality.

5.8.2 Strategic Recommendations for a Resilient Basin

1. **Mobilise sustainable and innovative finance**: Broaden financing through green and blue bonds, climate and results-based instruments, and payments for ecosystem services, while incentivising private-sector investment in circular-economy models for waste and wastewater reuse. Establish a Lake Victoria Basin Water Quality Trust Fund—a US$100 million endowment jointly capitalised by governments, development partners, and the private sector—to sustain long-term monitoring, innovation, and ecosystem restoration. Enforce a basin-wide polluter-pays regime to fund recurrent operations, and intensify advocacy for domestic budget allocations to water quality management and pollution control, covering both infrastructure and operational costs. Priority attention should be given to fully funding the Lakewide Inclusive Sanitation (LWIS) Strategy and the initial phases of the LVB Integrated Water Resources Management (IWRM) Programme.
2. **Reduce pollution at source:** Accelerate wastewater, fecal-sludge, and solid-waste management in urban and industrial hotspots through a blend of engineering and nature Based Solutions (NbS) for waste management; promote catchment stewardship through climate-smart agriculture, erosion control, and wetland restoration; address emerging pollutants—including plastics, mining waste, hazardous waste, and POPs—through integrated waste-management and recycling facilities; and scale circular-economy and nature-based solutions such as nutrient recovery, plastic recycling, and biogas production.
3. **Build resilience through adaptation and public engagement:** Integrate climate-risk screening and "climate-proofing" into all new WASH and drainage infrastructure, and sustain basin-wide awareness and education campaigns that foster behavioural change

in waste handling, farming, and resource stewardship.

4. **Strengthen the evidence base:** Institutionalise a regular, co-financed transboundary water-quality survey anchored by an operational ***RV Jumuiya***; adopt a binding regional data-sharing protocol with standardised parameters, formats, and QA/QC procedures; and deploy a hybrid monitoring system combining Earth observation, real-time sensors, and targeted in-situ sampling for calibration and validation.
5. **Harmonise governance and enforcement:** Fast-track pending EAC instruments and align national standards with regional benchmarks; adequately resource inspectorates and strengthen integrity systems; empower community co-management structures such as Beach Management Units for local compliance; and develop and routinely test a coordinated transboundary spill-response plan.

5.8.3 Development of a Water Quality Index for Lake Victoria Basin

5.8.3.1 Introduction

In addition to the strategic recommendations above, another key recommendation for the sustainable management of the Lake Victoria Basin is the development of a Water Quality Index (WQI) for the lake and its influent rivers.

Current water quality monitoring in the Lake Victoria Basin generates substantial technical datasets. However, these datasets—comprising turbidity measurements, dissolved oxygen levels, nutrient concentrations, bacteriological counts, and macroinvertebrate indices—remain largely incomprehensible to the primary stakeholders who must act upon them. Policy makers, local government officials, community leaders, and citizens struggle to translate numerical values into meaningful assessments of risk, urgency, and required action. For a non-technical stakeholder, a Phosphorus concentration of 0.1 mg/L or a fecal coliform count of 500 cfu/100 mL carries little intuitive meaning regarding safety or urgency. This technical-practical gap fundamentally undermines the utility of water quality monitoring investments and impedes evidence-based decision-making.

A Water Quality Index (WQI) for Lake Victoria would synthesize multiple metrics into a single, intuitive score presented through colour-coded classification (e.g., blue for pristine, green for good, yellow for fair, orange for polluted, and red for heavily polluted). This approach, successfully implemented in water bodies globally—including the Canadian Water Quality Index, Oregon Water Quality Index, and indices used for the Ganges and Mekong rivers—transforms complex datasets into actionable intelligence accessible to all stakeholder categories.

5.8.3.2 Justification and rationale

Lake Victoria's water-quality pressures—eutrophication, fecal contamination, industrial pollution, sedimentation, and emerging contaminants—require tools that translate monitoring into action. A basin WQI would: (i) strengthen policy responsiveness by enabling rapid identification of priority hotspots and clear communication of trends; (ii) support regulatory compliance by embedding national standards and relevant regional protocols (including the Water Quality Objectives referenced above) into the index; (iii) improve resource allocation through spatial mapping that targets interventions where risk is highest; (iv) enhance public engagement by making water-quality information accessible and actionable; and (v) provide a shared framework for transboundary cooperation among Partner States (Kenya, Tanzania, Uganda, Rwanda, Burundi) through a common language for assessment, coordination, and accountability. A standardised WQI also strengthens trend reporting and aligns with obligations under SDG 6.3.2, the Ramsar Convention, and LVBC protocols.

5.8.3.3 Methodological soundness

Modern WQI methods can reflect Lake Victoria's multi-stressor context by combining physical (e.g., turbidity, conductivity), chemical (e.g., dissolved oxygen, nutrients, pH, heavy metals), and biological (e.g., fecal indicators, chlorophyll-a, macroinvertebrates) parameters, with optional inclusion of emerging issues (e.g., microplastics, pharmaceuticals) where data permit. Index formulation can apply scientifically defensible weighting and aggregation approaches (e.g., weighted arithmetic, multiplicative, or minimum-operator methods) while maintaining interpretability for non-technical users.

5.8.3.4 Conclusion and recommendation

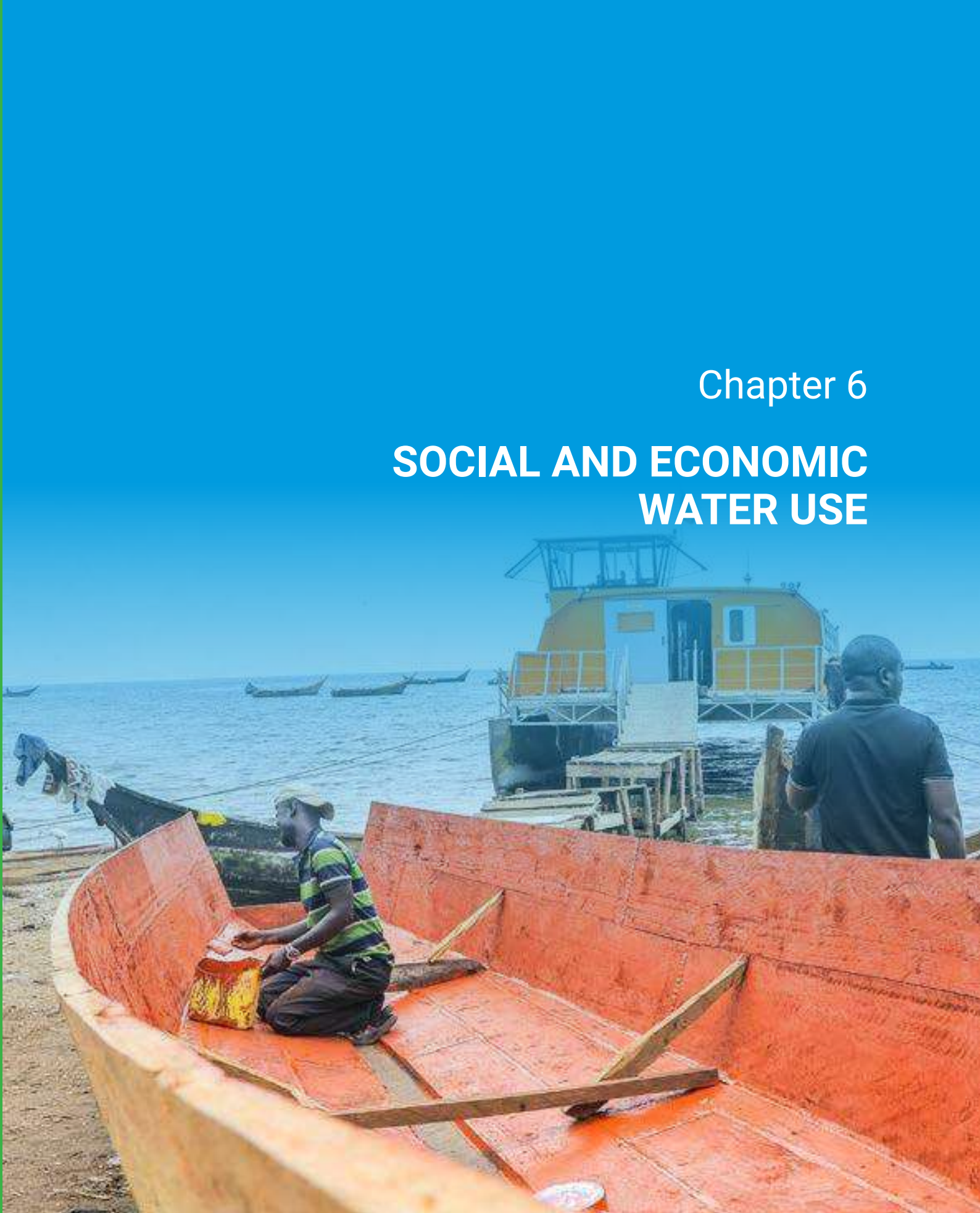
A WQI is more than a reporting tool: it is a shift from passive monitoring to risk-based, actionable governance. It is recommended that the Lake Victoria Basin Commission (LVBC) convene a regional technical committee to develop and pilot a basin-specific WQI that reflects the lake's tropical limnology and the socio-economic pressures shaping water quality in influent rivers.

SECTION III

Water Use, Development and Climate Change

Chapter 6

SOCIAL AND ECONOMIC WATER USE



SUMMARY - CHAPTER 6

Chapter 6 provides an integrated assessment of how the Basin's major water-dependent sectors—water supply sanitation and hygiene (WASH), agriculture, fisheries and aquaculture, energy, navigation, and tourism—are evolving, the pressures they exert, and the opportunities they create for inclusive, climate-resilient development. It synthesises long-term trends, sectoral performance, and emerging geographic hotspots, illustrating how environmental degradation and climate variability are reshaping sectoral risks. The chapter concludes by examining basin-wide water allocation as a cross-cutting governance challenge: how growing, spatially concentrated demands and declining water quality heighten trade-offs, but also create opportunities for smarter, more equitable, and ecologically grounded management to secure Lake Victoria's long-term sustainability



Water Supply and Environmental Sanitation

WASH access is improving but deeply unequal – All Partner States have expanded basic drinking water, yet sanitation and hygiene lag far behind, with large inter-country and rural–urban



Fisheries and Aquaculture

Fisheries and aquaculture are economic and nutritional pillars, supporting 3–4 million livelihoods and contributing over USD 1.1 billion in annual beach value, yet their true footprint is underrepresented in national GDP accounts.



Agricultural Water Use

Agriculture is the Basin's largest water user and main livelihood source, yet productivity remains low due to reliance on rainfed systems, increasing climate variability and extreme weather events,



Navigation

Lake Victoria's inland water transport is re-emerging as a strategic, low-carbon backbone for EAC regional integration, linking Northern and Central Corridors and enabling the Basin to benefit from AfCFTA-driven trade growth.

Key Messages

Water Supply and Environmental Sanitation

1. **WASH access is improving but deeply unequal** – All Partner States have expanded basic drinking water, yet sanitation and hygiene lag far behind, with large inter-country and rural–urban disparities that leave millions exposed to preventable disease and undermine human development..
2. **Urban WASH systems are fragile and pollution-intensive** – Rapid, largely unplanned urbanisation has outpaced investment in sanitation, fecal sludge management, stormwater, and solid waste infrastructure, turning cities into major sources of pathogen and nutrient loads entering Lake Victoria.
3. **Informal and marginalised communities bear the highest burden** – Informal urban settlements, fishing communities and rural institutions (schools, health centres) are the least served, facing unsafe water, inadequate sanitation, and minimal hygiene facilities, with disproportionate impacts on women, girls, and low-income households.

Agricultural Water Use

4. **Agriculture is the Basin's largest water user and main livelihood source**, yet productivity remains low due to reliance on rainfed systems, increasing climate variability and extreme weather events, and limited input use (low fertilizer application rates, limited access to improved seeds, and minimal use of mechanization).

5. **Irrigation offers major economic potential but remains severely underdeveloped**, despite substantial untapped water and land resources.
6. **Rainfed farming faces deep structural challenges**, with declining soil fertility, severe erosion, and growing climate extremes driving persistent yield gaps and heightened vulnerability.
7. **Livestock water stress is intensifying**, especially in semi-arid zones, where seasonal scarcity, long-distance trekking, and poorly maintained water points reduce herd productivity and increase conflict and disease risks.

Fisheries and Aquaculture

8. **Fisheries and aquaculture are economic and nutritional pillars**, supporting 3–4 million livelihoods and contributing over USD 1.1 billion in annual beach value, yet their true footprint is underrepresented in national GDP accounts.
9. **The capture fishery is in biological overexploitation**, with rising total landings maintained by a shift toward Dagaa and other lower-value species, masking overfishing of Nile perch, pervasive IUU fishing, and degrading habitats.
10. **Aquaculture—especially cage culture—is expanding rapidly but unsustainably**, constrained by costly feed and fingerlings, disease transmission, and contaminant bioaccumulation.
11. **A sustainable Blue Economy transition is still possible**, but requires stronger transboundary governance and Monitoring, Control and Surveillance, tighter regulation of cage aquaculture, investment in cold chains and value addition, and technologies and finance that build resilience for small-scale actors.

Hydropower Generation and Regional Power Interconnection

12. **Hydropower remains the backbone of the Basin's power system**, supplying most low-cost baseload electricity—but its reliability is increasingly threatened by climate variability, sedimentation, and watershed degradation.
13. **Diversification is urgent to reduce hydrological risk**, requiring accelerated investment in geothermal, solar, wind, mini-grids, and clean cooking to ease pressure on forests and hydropower assets.
14. **Electricity access is improving but deeply unequal**, with large gaps between and within countries; rural communities remain the most underserved despite rising generation capacity.
15. **Regional power interconnection is on the increase**, enabling countries to pool reserves, stabilize supply during droughts, utilise Uganda's large surplus, and lower overall system costs through least-cost regional dispatch.

Navigation

16. **Lake Victoria's inland water transport is re-emerging as a strategic**, low-carbon backbone for EAC regional integration, linking Northern and Central Corridors and enabling the Basin to benefit from AfCFTA-driven trade growth.
17. **Intermodal connectivity is the make-or-break issue**: the competitiveness of IWT depends on seamless interfaces with metre-gauge and standard-gauge rail, efficient Ro-Ro operations, and upgraded road links at Kisumu, Mwanza, Port Bell, and future Bukasa.
18. **Ports, fleets, and digital safety systems are being modernised**, but Uganda's lagging port infrastructure, fragmented governance, and poor enforcement in the vast small-boat fleet still constrain performance and safety.
19. **Lake Victoria remains one of the world's deadliest inland waterways**, with thousands of annual drownings; closing the regulatory gap for informal vessels and fully operationalising the Multinational Lake Victoria Maritime Communications and Transport safety and weather-information system are urgent life-saving priorities.

Tourism

20. **Tourism is a major economic engine in the Lake Victoria Basin**, contributing significantly to GDP, exports, and jobs across Partner States—but the Basin's lake tourism potential remains underdeveloped relative to its world-class terrestrial parks.

21. **Infrastructure weaknesses—especially poor roads, inadequate sanitation, and outdated lake transport—constrain competitiveness**, despite strong regional air connectivity and recent improvements in maritime safety.
22. **A sustainable future depends on regional coordination and community participation**, with stronger EAC–LVBC alignment, harmonised standards, climate-resilient planning, and empowered community-based tourism models to ensure equitable benefits and ecosystem protection.

Water Use Projections and Coping Strategies

23. **Lake Victoria's water security is inflow-limited, not volume-limited**: Net Basin Supply of only ~20–30 BCM/year is tightly constrained by the balance of rainfall and evaporation, making the system highly sensitive to climate variability despite the lake's large storage.
24. **Climate change will likely bring a wetter but far more volatile Basin, with more frequent floods and deeper droughts**; while a basin-wide physical deficit is unlikely in the near term, sub-basin shortages and tensions around Nile outflows become increasingly probable under high-demand scenarios.
25. **Water quality is emerging as the binding constraint on water security**, as escalating nutrient loads, pollution and eutrophication effectively reduce usable supply and drive up treatment costs—creating a pollution–scarcity paradox even where volumes remain adequate.
26. **Long-term resilience depends on demand management, smarter allocation, and investment in natural and built infrastructure**, including economic instruments and "virtual water" trade, efficiency gains in irrigation, protection of wetlands and water towers, expanded wastewater and fecal sludge management, stronger water information systems, and scaled climate and blended finance for resilient, high–value water use.



Figure 6-1. *A tomato farmer in Lower Kuja Irrigation Scheme, Migori County, Western Kenya. (Source: National Irrigation Authority, Kenya).*

Key State Indicators – Water Use, Development and the Blue Economy (2025)

Strategic & Thematic Areas	Indicator / Metric	Value / Range (2025)
E4 Renewable energy resources		
E4.1 Renewable energy installed	Installed renewable capacity – Burundi	77 MW
	Installed renewable capacity – Rwanda	182 MW
	Installed renewable capacity – Tanzania	1,478 MW
	Installed renewable capacity – Uganda	1,818 MW
	Installed renewable capacity – Kenya	3,051 MW
E4.2 Renewable energy potential	Estimated renewable potential – Burundi	~3,500 MW
	Estimated renewable potential – Rwanda	~2,500 MW
	Estimated renewable potential – Tanzania	~13,000 MW
	Estimated renewable potential – Uganda	~10,000 MW
	Estimated renewable potential – Kenya	~20,000 MW
W4 Water resources development		
W4.1 Artificial storage (dams)	Major dams (excluding Nalubaale/ Kiira complex)	10 dams
	Total storage capacity	~891.85 MCM
W4.2 Hydropower development	Installed capacity (14 power stations)	~760.8 MW
	Additional capacity (downstream of Jinja)	~1,033 MW
	Total installed hydropower capacity	~1,793.8 MW
W4.3 Irrigation	Number of large irrigation schemes	31 schemes
	Area equipped for irrigation	~114,012 ha
W4.4 Inter-basin transfers	Volume of inter-basin transfers	~214 MCM per year
	Number of transfer schemes	5 schemes (Kenya, Tanzania, Uganda)
W4.5 Water requirements / demands	Irrigation demand	~666.9 MCM per year
	Domestic and industrial demand	~1,376.5 MCM per year
	Livestock demand	~109.4 MCM per year
	Wildlife and fisheries demand	~40.8 MCM per year
	Out-of-basin transfers	~214.4 MCM per year
	Total consumptive water demand	~2,408 MCM per year
	Water stress (share of renewable resources)	~8 %
W4.6 Environmental flows and adherence	Status of e-flows assessment and compliance	Information limited
S3 Maritime and blue economy		

Strategic & Thematic Areas	Indicator / Metric	Value / Range (2025)
S3.1 Lake transport	Inland water transport (IWT) contribution to regional GDP	~4 %
	Livelihoods supported by IWT	~5 million people
	Key lake ports	Kisumu, Mwanza, Port Bell, Jinja, Bukasa, Bukoba, Musoma, Kemondo Bay
	Modern vessels	~10 vessels
	Informal wooden boats	~50,000 boats
S3.2 Fish production	Capture fisheries production	~1.14 million tonnes/year
	Annual beach value of fisheries	~US$1.12 billion
	Livelihoods supported	~3–4 million
	Direct employment	~250,000
	New fish farms (2021)	55
	Aquaculture production	No data
S3.3 Emergence of marine-based industries	Status of marine-based industries	Emerging; limited data
S3.4 Maritime insurance	Availability of maritime insurance cover	Insufficient information



6.1 Water Supply and Environmental Sanitation

Water supply and environmental sanitation represent the fundamental infrastructure upon which human health, economic productivity, and environmental sustainability in the Lake Victoria Basin depend. **Section 6.1** examines the critical nexus between service delivery and lake ecology by tracing basin-wide patterns of access, service quality, and pollution pathways. It begins by documenting the uneven trajectory of WASH improvements across Partner States, revealing persistent disparities that expose millions to preventable disease. The analysis then demonstrates how degraded source waters, aging infrastructure, and governance weaknesses undermine urban and rural water systems. Subsequent sections assess how inadequate sanitation and solid waste management generate pathogen and nutrient loads that flow untreated into the lake. Understanding these interconnected failures—and the barriers that perpetuate them—is essential for interpreting the basin's water quality crisis and designing interventions that advance public health, reduce pollution, and build resilience against rapid urbanization and climate change.

6.1.1 Overview and Trends

Water supply and environmental sanitation form the foundation of human wellbeing and sustainable development in the Lake Victoria Basin (LVB). Yet low funding of the sector, rapid population growth, unplanned urbanization and weak waste management systems have left large segments of the population without safely managed water and sanitation. Untreated sewage and industrial effluents routinely enter rivers such as the Nyando, Nzoia, and Mara, transporting high pathogen loads into Lake Victoria (see Chapter 5; Shapiro et al., 1999). As a result, many communities depend on contaminated surface waters for drinking, cooking, and bathing.

The United Nations recognises access to safe, affordable, and culturally acceptable water and sanitation as a human right (UN General Assembly, 2010; UNCESCR, 2002), yet persistent service gaps across the basin expose households to preventable illness. Waterborne diseases—including cholera, typhoid, dysentery, and childhood diarrhoea—remain endemic, with lakeshore and fishing communities at particularly high risk (Mbo Mvumba et al., 2024; LVBC, 2024a).

These health burdens erode productivity, deepen poverty, and reinforce environmental pressures. Expanding equitable WASH services is therefore essential to safeguard public health and build long-term resilience in the LVB.

6.1.2 Trends in Drinking Water, Sanitation, and Hygiene (WASH) Access

The three WASH indicators—basic drinking water **(Figure 6-2)**, basic sanitation **(Figure 6-3)**, and basic hygiene **(Figure 6-4)**—show a consistent but uneven trajectory of improvement across the Lake Victoria Basin (LVB) Partner States. While all countries have made progress since 2000, the trends reveal significant inter-country disparities, slower gains in sanitation and hygiene than in drinking water, and areas of stagnation that carry major implications for public health, lake ecology, and the Basin's socio-economic development.

Access to basic drinking water services (**Figure 6-2**) has increased steadily across the region, with particularly strong progress in Rwanda, Kenya, and Uganda. Rwanda remains the regional leader, rising from just under 50% in 2000 to nearly 75% in 2024. Kenya and Uganda show marked acceleration after 2015, with Kenya approaching 70% and Uganda roughly 68–70% by 2024. Tanzania's progress is steady but more moderate, climbing to about 60%. Burundi remains the slowest performer, improving only marginally over two decades. A noticeable increase after 2022 across several countries may reflect intensified investment or methodological updates. Overall, the region is converging upward on drinking water access, although internal inequality persists.

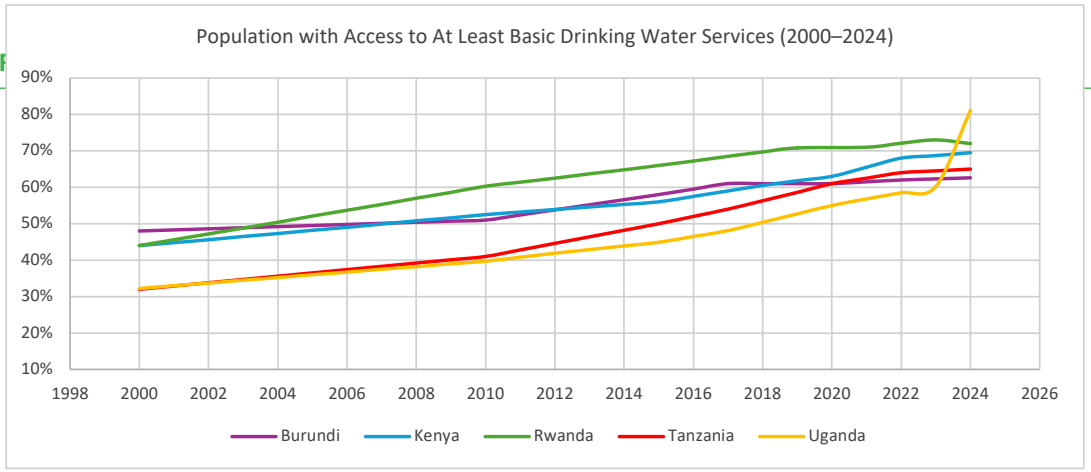


Figure 6-2. *Percentage of population of the LVB Partner States with access to at least basic water supply (2000–2024). (Sources: WHO/UNICEF JMP (2021, 2025); NISR (2015, 2021, 2023, 2024); UBOS (2001, 2006, 2024); KNBS & ICF (2023); NBS & ICF (2016, 2023); UNICEF Burundi (2023); World Bank (2023)).*

By contrast, **access to basic sanitation (Figure 6-1)** shows **slower and more uneven progress**, with wide and widening disparities. Rwanda stands out as the regional leader, rising from around 40% in 2000 to nearly 70% in 2024 despite temporary dips due to definitional revisions. Rwanda's exceptional progress can be attributed to several interrelated factors including strong political commitment with presidential leadership giving high profile to sanitation; implementation of the Community-Based Environmental Health Promotion Programme (CBEHPP) under the Ministry of Health, which installed pit latrines in over 84% of rural households; adoption of Community-Led Total Sanitation (CLTS) approaches that reduced open defecation to 1% across the country; and targeted investment in rural areas where most of the population resides (Ekane et al., 2020; UNICEF, 2021). Tanzania exhibits a major upward shift after 2010, reaching about 55–58% in 2024. Kenya's progress is moderate, increasing from the low 20s to just above 40%. Uganda and Burundi, however, remain critically low, with Uganda climbing only slightly—from 17% to about 23–25%—and Burundi plateauing near the low 40s. Unlike drinking water access, sanitation trends show divergence rather than convergence, emphasizing structural gaps in policy, financing, and rural service delivery.

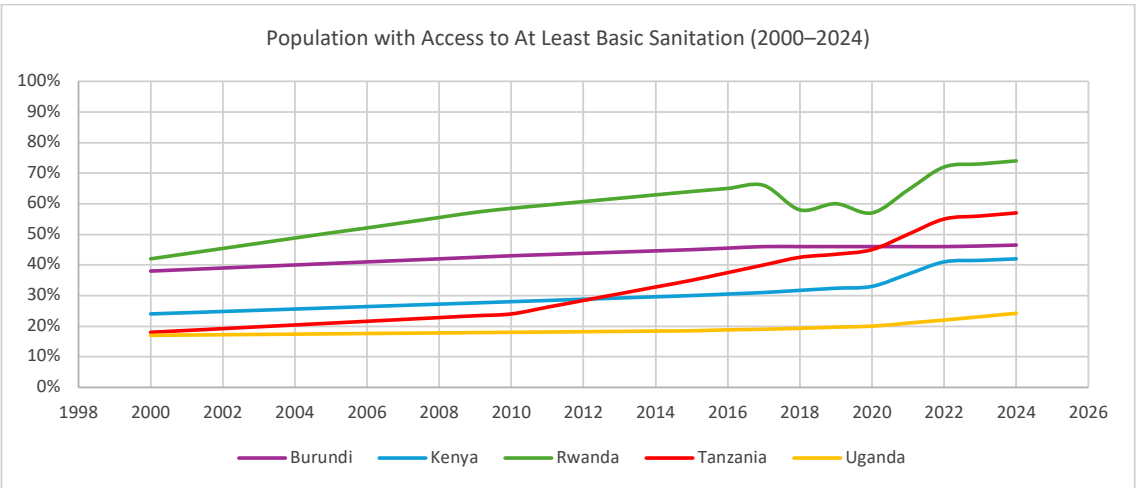


Figure 6-3. *Percentage of population of the LVB Partner States with Access to At Least Basic Sanitation (2000–2024). (SourcesWHO/UNICEF JMP (2021, 2025); KNBS & ICF (2023); NISR (2015, 2021, 2023); NBS & ICF (2016, 2023); UBOS (2001, 2006, 2024); UNICEF Burundi (2023)).*

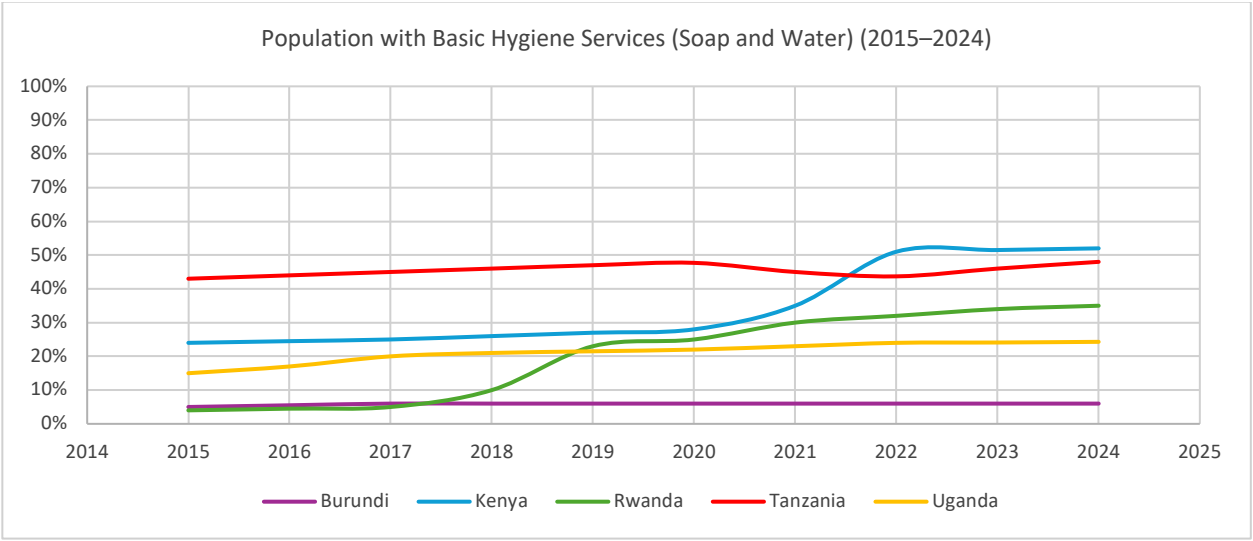


Figure 6-4. *Percentage of population of the LVB Partner States with Access to At Least Basic Hygiene services (soap and water at residence) (2000–2024). (Sources: WHO/UNICEF JMP (2021, 2025); KNBS & ICF (2023); NISR (2015, 2021, 2023); NBS & ICF (2016, 2023); UBOS (2001, 2006, 2024); UNICEF Burundi (2023)).*

Basic hygiene services—access to a handwashing facility with soap and water—represent the weakest of all WASH indicators (**Figure 6-4**). Tanzania and Kenya show the strongest improvements, reaching approximately 50% by 2024, with Kenya experiencing a steep post-COVID-19 jump driven by national hygiene campaigns. Rwanda improves steadily from very low levels to about 32–33%, but still lags behind its strong performance in drinking water and sanitation. Uganda progresses slowly, reaching only 23–25%. Burundi shows almost **no improvement**, remaining at 5–6% throughout the entire 2015–2024 period. This demonstrates the profound challenge of enabling household-level behaviour change and ensuring widespread access to affordable soap and reliable water for handwashing.

Taken together, the three charts reveal a WASH landscape characterised by steady long-term improvements, but also by critical weaknesses—particularly in sanitation and hygiene—that directly affect health outcomes, environmental quality, and the sustainability of key economic sectors such as fisheries and tourism.

6.1.3 Urban Water Supply

The Lake Victoria Basin (LVB) is undergoing one of Africa's fastest urban transitions, with annual population growth exceeding 3.5% and major cities—Kampala, Kisumu, Mwanza, and Kigali—expanding rapidly, often through unplanned settlements lacking basic services. These dynamics are intensifying pressure on already-strained urban water systems. By 2050, the basin's population is projected to reach 165 million, sharply increasing municipal and industrial water demand (IIASA, 2021).

Despite broad progress in expanding basic water access, a substantial "service-ladder gap" persists between basic and safely managed services. As shown in **Table 6-1**, most LVB countries achieve high coverage of basic water supply (>85%), yet safely managed services remain far lower—41% in Uganda and 51% in Tanzania (WHO & UNICEF, 2023).

Table 6-1. **Urban Population with Access to Drinking Water Services (%, 2022) (Source: WHO & UNICEF (2023).**

Partner State	Urban Population (%)	Basic Access (%)	Safely Managed (%)
Burundi	15	89	N/A
Kenya	30	95	68
Rwanda	19	97	70
Tanzania	38	87	51
Uganda	28	89	41

A structural dependence on surface water poses increasing risks. Kampala, Kisumu, and Mwanza rely heavily on near-shore intakes located in polluted bays (e.g., Murchison Bay, Winam Gulf). Degraded source water significantly increases treatment costs and undermines compliance with potable water standards (EAS 12; WHO). Utilities face a self-reinforcing cycle: untreated urban wastewater contaminates intake zones, lowering treatment efficiency and diverting scarce finances from essential sanitation and network investments.

Utility performance data reveal systemic vulnerabilities (**Table 6-2**). Non-Revenue Water—a combined effect of aging infrastructure, leaks, and metering losses—remains critically high: 34% in Uganda, 44% in Kenya, and 40% in Burundi. Most utilities also operate under non-cost-reflective tariffs, preventing full cost recovery and limiting capital investment. As a result, distribution networks deteriorate, service reliability weakens, and utilities remain financially fragile. Utility compliance with national and East African potable water standards remains uneven, with degraded source waters in near-shore intakes increasing treatment burdens and heightening the risk of intermittent non-compliance, particularly during peak pollution and algal bloom periods (JICA, 2021).

Table 6-2. **Key Utility Performance Indicators (FY 2023/24) (Source: WASREB (2025); NWSC (2025); EWURA (2025); World Bank (2025)).**

Country / Utility	Service Coverage	Non-Revenue Water	Bill Collection Efficiency	O&M Cost Recovery
Kenya (WSP Avg.)	70% piped	44%	95%	98%
Uganda (NWSC)	84%	34%	N/A	N/A
Tanzania (WSSA)	84%	High (>20%)	N/A	98%
Rwanda (WASAC)	97% urban improved	N/A	N/A	N/A
Burundi (REGIDESO)	8.5% national piped access	40% (2019)	80%	Not recovered

Service inequity remains acute. Informal settlements, lacking formal connections, rely on vendors and kiosks where water prices far exceed utility tariffs—forcing the poorest households to pay the most.

These challenges, compounded by climate variability and rising demand, pose a major threat to urban water security. Without major investment in source protection, network rehabilitation, and pro-poor service models, the basin's rapidly growing cities will face worsening supply deficits and escalating public-health risks.

6.1.4 Rural Water Supply

Rural water supply is central to the wellbeing and productivity of the majority of residents in the Lake Victoria Basin (LVB). While groundwater is the region's primary rural water source, its reliability and safety are increasingly compromised by rapid population growth, sanitation failures, and weak governance. As a result, the rural challenge is not only expanding access but raising service levels from "basic" point sources to safely managed water—reliable, on-premises, and free from contamination (WHO & UNICEF, 2024) (**Figure 6-5**).



Figure 6-5. *A water kiosk in western Kenya providing safe piped water to rural communities. Source: World Bank).*

The LVB remains predominantly rural, home to over 45 million people, most reliant on smallholder agriculture. Population densities of 350–2,000 persons/km² in highland and lakeshore zones exert growing pressure on shallow aquifers (World Bank, 2022). Projections suggest the rural population could rise to 113–165 million by 2050, driven by high fertility and a youthful demographic structure. This growth increases domestic water demand and heightens nitrate and fecal contamination of groundwater, as nearly 70% of households use unlined pit latrines—often within 10–20 metres of wells and springs. Without major improvements in sanitation, even significant rural water-supply investments will fall short of achieving safely managed service levels.

With regard to service coverage and access levels, the basin shows a consistent pattern: rural areas lag significantly behind urban areas, and the gap between "basic" and "safely managed" water is especially large. Basic access may indicate the presence of a functioning water point, but safely managed water—measured by reliability, proximity, and water quality—remains extremely low or unreported. Monitoring gaps are also acute (**Table 6-3**): Kenya, Rwanda, and Burundi do not report on safely managed data, complicating national planning and regional comparisons.

Table 6-3. Rural Drinking Water Service Levels (JMP 2022–2024)

Country	Basic (%)	Safely Managed (%)	Unimproved / Surface (%)	Key Insight
Burundi	61.4	No data	38.6	Heavy reliance on springs; major data gaps
Kenya	55.6	No data	24.9	Large unregulated rural sector
Rwanda	84.0	No data	N/A	High basic access but no safety data
Tanzania	28.5	22.8	34.8	Very low access overall
Uganda	46.8	18.1	26.2	Wide gap between basic and safe

Rural water supplies rely predominantly on groundwater, accessed through boreholes, shallow wells, protected springs, and in some areas gravity-fed piped schemes. Within this overall pattern, there are country differences:

- **Uganda** relies heavily on deep boreholes with handpumps, complemented by springs and small piped schemes (Ministry of Water & Environment Uganda, 2020).
- **Burundi** depends on natural springs (≈90% of supply), many unprotected and highly seasonal (World Bank, 2015).
- **Rwanda** utilizes spring-fed gravity systems due to its steep terrain (Ministry of Infrastructure Rwanda, 2016).

A major structural constraint is the prevalence of 5-inch handpump boreholes, drilled over decades. These cannot accommodate electric or solar-powered submersible pumps used in modern piped schemes, locking communities into low-yield technologies. Transition to higher-level service thus requires complete borehole replacement, representing a major capital burden for Partner States.

Groundwater is often assumed to be inherently safe, yet evidence from the Lake Victoria Basin shows widespread contamination arising from both natural geological conditions and human activities. In northern Tanzania, arsenic associated with gold-bearing formations exceeds WHO standards in up to 48% of tested samples (World Bank, 2018), while fluoride is prevalent across Kenya's Rift-influenced regions, contributing to skeletal and dental fluorosis. Human-induced contamination is equally significant: in Kisumu County, 75% of shallow wells surpass nitrate limits due to leakage from pit latrines and agricultural inputs, and studies across the Lake Victoria Basin indicate that 60–95% of rural water sources across Burundi, Kenya, Rwanda, Tanzania and Uganda test positive for E. coli, underscoring the pervasive nature of fecal contamination in shallow groundwater (Fejfar et al., 2024; Kirby et al. 2016; Opisa et al., 2012; Misati et al., 2017; Tumusiime et al., 2019; Lauer et al., 2019).

Rural water quality monitoring is extremely limited; in some countries, such as Burundi, systematic testing does not exist (World Bank, 2015). As a result, contamination often goes undetected, leaving communities exposed to waterborne diseases.

High failure rates—around 26% of handpumps nonfunctional at any moment—reflect structural weaknesses in rural water management (Foster et al., 2019). Systems frequently fall into disrepair due to underfunded, reactive maintenance. In Uganda, less than 1% of the sector budget goes to O&M (UNICEF, 2024a), illustrating the Basin-wide "build–neglect–rebuild" cycle.

6.1.5 Urban Sanitation and Pollution Control

Rapid and largely unplanned urbanisation across the Lake Victoria Basin has outpaced investments in sanitation and wastewater management, leaving an estimated 33 million people without improved sanitation—a deficit heavily concentrated in expanding cities and peri-urban areas (World Bank, 2023). As documented in

Chapter 2, these demographic trends have intensified pressure on already weak municipal systems, making urban sanitation one of the basin's most persistent drivers of pathogen and nutrient pollution.

Although most Partner States report relatively high access to basic sanitation, the proportion of households with safely managed services—where waste is adequately contained, transported, treated, and disposed—remains very low across the basin. Recent national surveys reveal wide disparities in service levels, with some countries reporting strong progress on basic coverage but limited sewered or safely managed options, and with open defecation persisting in certain dense urban settlements. These contrasts are summarised in **Table 6-4**.

Table 6-4. Urban Sanitation and Hygiene Coverage in LVB Partner States (2022–2024)

Country	Basic Sanitation (Urban)	Safely Managed Sanitation (Urban)	Basic Hygiene	Urban Open Defecation	Key Sources
Burundi	No data	No data	No data	No data	
Kenya	93%	36%	48%	3%	Dept. Committee (2025); UN-Habitat (2023)
Rwanda	94%	n/a	n/a	n/a	NISR (2024)
Tanzania	55% (National)	n/a	n/a	10%	NBS & ICF (2023)
Uganda	89% basic sanitation; 8% sewered (Kampala)	21%	n/a	1.8% (Kampala)	WHO & UNICEF (2023)

Note: *n/a indicates unavailable or incomparable disaggregated data.*

Textbox 6-1 below compares sanitation in the cities of Kigali and Mwanza, highlighting the wide divergence in sewered sanitation across the region.

Textbox 6-1: Contrasting Sanitation Pathways in Kigali and Mwanza – A Greenfield–Brownfield Divide

Kigali and Mwanza illustrate two sharply different trajectories in urban sewerage development. Kigali remains entirely unsewered, with 0% of its population connected to a centralized network as it begins constructing its first system and the planned Giticyinyoni WWTP (EIB, 2017a). This greenfield approach targets high treatment standards—such as BOD < 25 mg/L and Ammonia < 5 mg/L—but faces prolonged design and implementation delays, leaving the city dependent on on-site sanitation for the foreseeable future (AfDB, 2025; EIB, 2017b).

Mwanza, by contrast, operates a small but functional sewerage network, serving 6–7% of the population and up to 23% in some wards (Sindo, 2024). Its low-technology Butuja Waste Stabilization Ponds comply with national effluent standards, achieving BOD 27 mg/L (limit 30 mg/L) and TSS 72 mg/L (limit 100 mg/L) (Tanzania Bureau of Standards, 2005). Mwanza's main constraint is collection: rapid population growth is outpacing network expansion, causing the proportion of connected households to decline over time (EWURA, 2024).

Together, these dynamics highlight a Greenfield–Brownfield paradox: Kigali is pursuing a modern, capital-intensive system from scratch, while Mwanza struggles to extend an existing but undersized network. The result is two contrasting sanitation futures—one delayed by development complexity, the other constrained by system reach.

Urban sanitation in the LVB is dominated by non-sewered systems—pit latrines, septic tanks, and hybrid non-sewered sanitation (NSS) options—which serve 75–90% of the urban population. Sewer networks remain limited, reaching only 8% of Kampala's residents and 16–25% of urban households in Kenya (WASREB, 2024). Because sewer expansion cannot keep pace with rapid urbanisation, fecal sludge management (FSM)—the collection, transport, treatment, and safe disposal of sludge—has become the most critical bottleneck in the sanitation chain.

Where sewerage and wastewater treatment plants (WWTPs) exist, many operate below capacity or discharge inadequately treated effluent. Kampala's Bugolobi WWTP has historically released partially treated sewage into the Nakivubo Channel, while new capacity in Kisumu, including the Otonglo plant, remains underutilised due to limited sewer connectivity (Pietroiusti et al., 2024). Consequently, untreated effluent and fecal sludge continue to be major pollution sources, contributing to eutrophication and high public-health risks.

Municipal wastewater alone delivers over 3,500 tons of nitrogen and 1,624 tons of phosphorus annually to Lake Victoria, illustrating the scale of the urban pollution burden (COWI, 2002). Although the EAC adopted regional effluent discharge standards in 2016, integration into national law has been uneven, weakening enforcement (World Bank, 2018). Industrial pollution adds further pressure, as many facilities still discharge untreated effluent into municipal sewers or directly into the environment due to weak pre-treatment requirements.

Given these constraints, basin-wide strategies increasingly emphasise professionalised FSM, especially in informal settlements where service gaps are greatest. Initiatives such as LVWATSAN and the Lakewide Inclusive Sanitation (LWIS) programme promote regulated, SME-driven collection and treatment models to expand safe services and reduce environmental pollution (World Bank, 2024). These approaches reflect a growing recognition that well-managed NSS systems can provide safe, scalable sanitation for rapidly growing urban areas.

6.1.6 Rural Sanitation and Hygiene

Rural sanitation in the LVB is marked by persistent service gaps that contrast sharply with progress in urban areas. While cities grapple with fecal sludge management and limited sewer coverage, rural communities confront the more fundamental challenge of achieving basic sanitation access and eliminating open defecation. The rural–urban divide is stark across Partner States: in Kenya, for example, nearly 90% of urban households have access to at least basic sanitation, compared with 31% in rural areas (WHO & UNICEF, 2023). Similar disparities are seen in Tanzania (urban 55% vs rural 22%) and Uganda (urban 48% vs rural 20%), demonstrating systemic inequality in service levels and institutional investment.

Across the basin, rural sanitation coverage remains well below national and regional targets. JMP 2022 estimates show that only Rwanda approaches universal rural access to basic and safely managed sanitation, while the remaining Partner States have low coverage and high open-defecation rates (**Table 6-5**). Open defecation is particularly entrenched in Tanzania (16%) and Uganda (17%), reflecting constraints in affordability, supply chains, behaviour change, and governance.

Table 6-5. **Rural Sanitation Coverage in LVB Partner States (2022) Source: WHO & UNICEF (2023).**

Country	Basic Sanitation (Rural)	Safely Managed (Rural)	Basic Hygiene (Rural)	Rural Open Defecation
Burundi	40%	34%	15%	15%
Kenya	31%	29%	23%	13%
Rwanda	64%	61%	40%	1%
Tanzania	22%	19%	22%	16%
Uganda	20%	18%	34%	17%

Sanitation conditions in rural institutions across the Lake Victoria Basin remain critically inadequate, with significant implications for public health, learning outcomes, and gender equity. In basin districts of Tanzania, only about **30% of rural schools** provide basic sanitation services, reflecting widespread shortages of functional latrines, water, and handwashing facilities (Ministry of Education and Vocational Training, 2023). Rural areas of Kenya and Uganda within the basin show similar institutional deficits, with school facilities frequently lacking private changing areas, soap, reliable water supply, and basic hygiene materials. These gaps make it difficult for many adolescent girls to manage menstruation safely at school, a pattern consistent with broader rural assessments in both countries (Hennegan et al., 2018). These institutional gaps, combined with broader household sanitation deficits in rural basin communities, significantly constrain infection prevention efforts in healthcare facilities and suppress school attendance and performance for girls.

Rural sanitation governance is shared across national ministries, local governments, and community organisations. Ministries of Health lead hygiene promotion, Ministries of Water oversee rural water supply, and Ministries of Education manage school WASH, while local governments—particularly Tanzania's LGAs—carry out most implementation. NGOs such as UNICEF and WaterAid provide essential technical and financial support and help drive behaviour-change initiatives.

The prevailing service-delivery model is Community-Led Total Sanitation (CLTS), which seeks to end open defecation by mobilising communities rather than offering hardware subsidies. In Kenya, strengthened "CLTS boosting" interventions have been shown to increase latrine ownership (Ong'ang'a et al., 2023). Yet CLTS has clear limitations: the poorest households often cannot afford durable latrines, supply chains for materials are weak in remote areas, and cultural norms can slow behaviour change. These constraints reinforce the wider poverty–environment trap that limits sustained sanitation improvements across the basin.

6.1.7 Municipal Solid Waste and Stormwater Management

6.1.6.1 Municipal Solid Waste Management

Solid waste management in LVB cities remains severely constrained by low collection coverage, inadequate financing, and the near absence of engineered disposal facilities (**Figure 6-5**). Waste generation is high and rising, but only a few urban centres operate functional landfills. Mwanza remains the basin's strongest performer: the city generates about 130,305 tons of waste annually and achieved a 76% collection rate in 2022, supported by a shared sanitary landfill serving Ilemela and Nyamagana districts (UN-Habitat, 2023b; Centre for Science and Environment, 2023). By contrast, Kisumu generates roughly 400 tons per day (~146,000 tons per year) but collects only 20–25% of waste, largely because it still relies on an open dumpsite and faces persistent contract failures and weak institutional coordination (Mascarenhas et al., 2019).

This pattern—high generation coupled with poor disposal—extends across most secondary towns in the basin, where open and unregulated dumpsites dominate. Uncollected waste frequently accumulates in drains, wetlands, and informal dumping grounds, contributing to groundwater contamination and degrading nearshore lake ecology. Recycling remains minimal; the informal sector performs nearly all materials recovery, diverting plastics, paper, and metals from final disposal, but operating in hazardous conditions without regulatory or social protection.



Figure 6-6. *Workers sort garbage at Nduba open landfill in Gasabo District, Kigali, Rwanda (Source: newtimes.co.rw.)*

A central lesson emerging from these cities is that a functional, engineered disposal site is the cornerstone of an effective municipal waste system. Without it, private collection contracts collapse, illegal dumping increases, and municipal authorities cannot sustain service coverage.

6.1.6.2 Municipal Stormwater Management

Stormwater management infrastructure in LVB cities is similarly inadequate and forms the primary pathway through which diffuse urban pollution reaches Lake Victoria. Most towns rely on undersized networks of natural channels, roadside drains, and culverts that cannot cope with rapidly expanding impervious surfaces (UN-Habitat, 2007). Climate change is amplifying these weaknesses: extreme rainfall events have become more frequent, and a recent attribution study confirmed that the 2020 Lake Victoria flooding—which produced record-high lake levels—was made more likely by anthropogenic climate change (Pietroiusti et al., 2024).

Poor solid waste management further undermines stormwater drainage. Drains and culverts are routinely clogged by uncollected refuse, causing widespread flooding during rainstorms. When overflows occur, stormwater becomes a highly polluted mixture carrying uncollected garbage, fecal sludge from overflowing latrines and sewers, and untreated municipal and industrial effluents directly into rivers and the lake (World Bank, 2022, 2025). No basin city operates stormwater pre-treatment systems, meaning virtually all runoff enters the lake untreated.

6.2: Agricultural Water Use

Section 6.2 examines how agriculture drives water demand in the Lake Victoria Basin and shapes basin-wide environmental outcomes. It outlines the sector's economic importance, the dominance of low-productivity rainfed farming, and the limited but strategic role of irrigation. The section maps where different production systems occur, analyses the pressures of climate variability, population growth, and land degradation, and details how agriculture contributes to sedimentation, nutrient loading, and chemical pollution in Lake Victoria.

6.2.1 Introduction and Context

Agriculture— in this chapter encompassing crops and livestock—is the central economic and social pillar of the Lake Victoria Basin (LVB). As outlined in Chapter 2, the sector employs over 70% of the basin's population yet contributes a much smaller share to national GDPs—typically 25–30% across the Partner States (KNBS, 2025; NISR, 2024; NBS, 2025; UBOS, 2024b; World Bank, 2020). This mismatch reflects a persistent low-productivity trap, where most production remains subsistence-oriented and highly vulnerable to climatic and market shocks (see Chapter 2). Sustainable intensification and improved water management therefore remain essential for raising household incomes and strengthening regional food security.

Agriculture is the largest water user in the LVB, characterised by two contrasting systems. Rainfed agriculture dominates and supports most smallholders, but productivity is highly sensitive to rainfall variability (see Chapter 7). Irrigated agriculture, though covering a small proportion of land, underpins high-value crops such as rice and sugarcane and represents a major opportunity for economic transformation (FutureWater, 2008; GRID-Arendal & Lake Victoria Basin Commission, 2022). This chapter assesses the water demands, productivity, and environmental impacts of both systems, including the important livestock sector.

Agricultural activity follows the basin's topography and climate (see Chapter 2.1). High-rainfall highlands in Kenya, Rwanda, and Burundi support dense, mixed smallholder farming, while irrigation clusters are concentrated in lowland plains and river valleys—such as Kenya's Kano Plains and the Mara River valley in Tanzania—where water abstraction is feasible (GRID-Arendal & Lake Victoria Basin Commission, 2022; FutureWater, 2008). Livestock, particularly pastoral systems, is more widely distributed across savanna and semi-arid zones (see Chapter 2).

Agricultural viability in the Lake Victoria Basin is shaped by three tightly linked pressures with direct consequences for water management. First, climate variability is increasing, with weaker long rains, more intense short rains, and degraded natural buffers causing even moderate dry spells to escalate into drought conditions for the 70% of farmers reliant on rainfed systems (see chapter 7). Second, rapid population growth—over 45 million people growing at 3.5–3.8% per year—is shrinking farm sizes and pushing cultivation onto steep slopes, riverbanks, and wetlands, accelerating land and soil degradation (see Chapter 2.2). Third, agriculture's impact on lake health is intensifying: erosion sends heavy sediment loads into rivers and the lake; fertilisers and livestock waste drive eutrophication and algal blooms; pesticide misuse introduces harmful residues; and expanding irrigation adds growing pressure on rivers and aquifers (see chapter 3 and chapter 5; GRID-Arendal & Lake Victoria Basin Commission, 2022). These interconnected dynamics underscore the need for integrated land and water management to sustain productivity while safeguarding the basin's ecosystems.

6.2.2 Rainfed Agriculture

Rainfed agriculture dominates the Lake Victoria Basin (LVB), accounting for more than 95% of the cultivated area and supporting the livelihoods of more than 70% of the basin's population (LVBC, 2025). It supplies the bulk of the region's staple foods—maize, bananas, cassava, sweet potatoes, beans, and sorghum—and thus remains foundational to basin-wide food security, rural incomes, and the stability of local markets. Typical farm sizes range between 0.5 and 2.5 ha, with particularly severe land pressure in Rwanda and Burundi where holdings average ~1 ha (FAO, 2011; Namubiru-Mwaura et al., 2017). Rapid population growth is accelerating land fragmentation, reducing fallow periods, and eroding the viability of smallholder production; under current productivity levels, 2–3 ha are generally required for households to achieve a living income (Silva et al., 2021).

Farming systems in the Lake Victoria Basin form a clear agroecological gradient (see **Figure 6-7)**: banana–coffee and root-crop systems dominate the densely populated, high-rainfall highlands of Uganda, Rwanda, and Burundi, while maize-based cereal systems prevail across western Kenya and northern Tanzania, where rainfall is seasonal and market access is stronger. Mixed pulses, cassava, and bean systems occupy the intermediate zones of central Uganda and north-western Tanzania, reflecting moderate rainfall and lower soil fertility. Root crops fringe the lake's southern and western shores, where poorer soils and rainfall variability favour drought-tolerant staples. Overall, the basin is characterised by high spatial diversity, with farming systems closely aligned to rainfall patterns, population density, soil conditions, and topography.

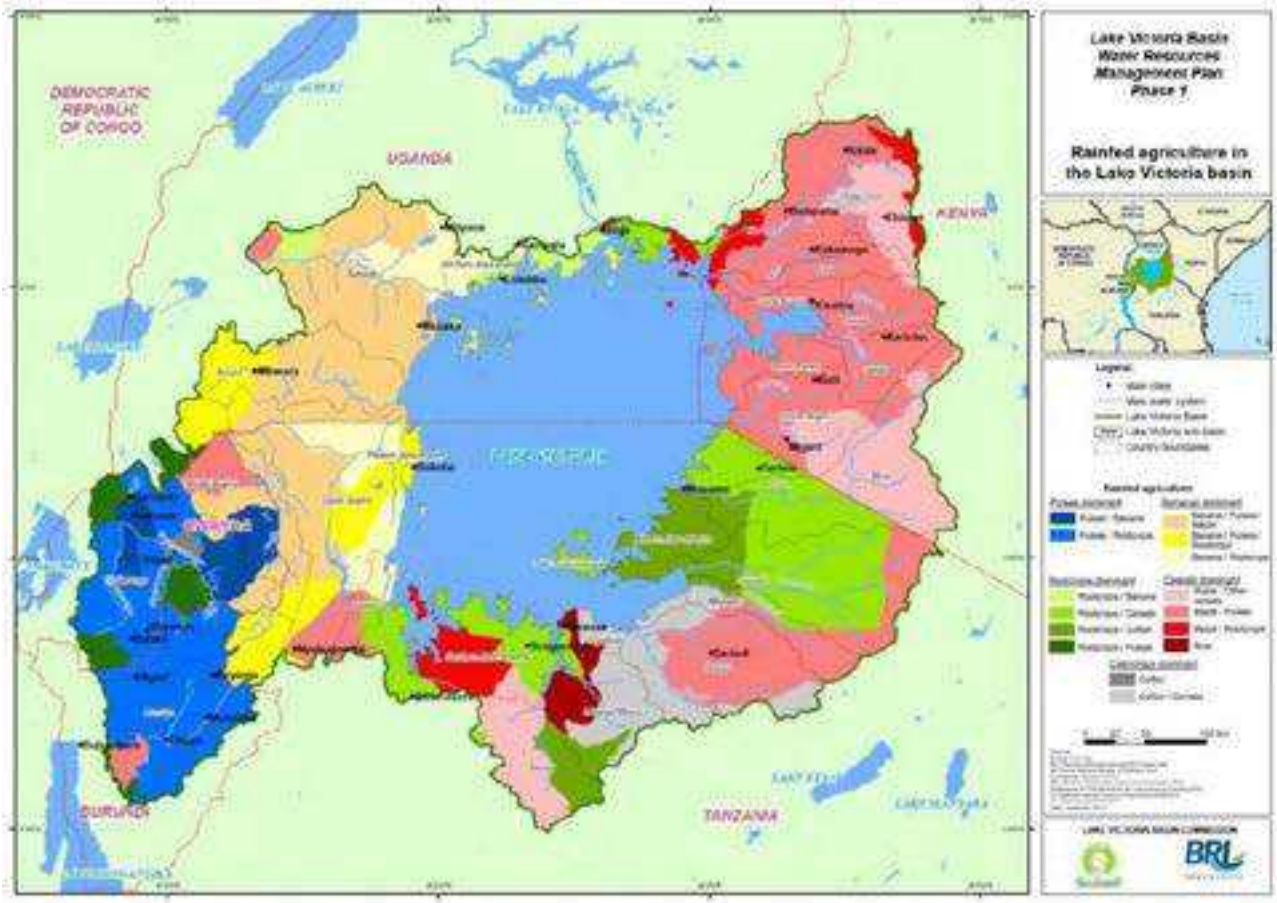


Figure 6-7. *Food crop farming systems in the Lake Victoria Basin (LVBC & BRL, 2014)*

Cash-crop farming in the Lake Victoria Basin similarly exhibits a clear agroecological structure **(see Figure 6-8)**: coffee dominates the highland zones of Uganda, Rwanda, and Burundi, forming one of Africa's most concentrated Arabica-producing regions; tea is clustered in the cool, moist highlands of western Kenya, southwestern Uganda, and parts of Rwanda and Tanzania; cotton is confined to the drier transitional zones of north-western Tanzania and small pockets of Uganda and Kenya; and sugarcane is concentrated in the warm, humid lowlands around Jinja, Mumias, and Kagera. Together, these patterns reflect strong alignment between cash-crop systems and the basin's gradients of altitude, rainfall, population density, and market access.

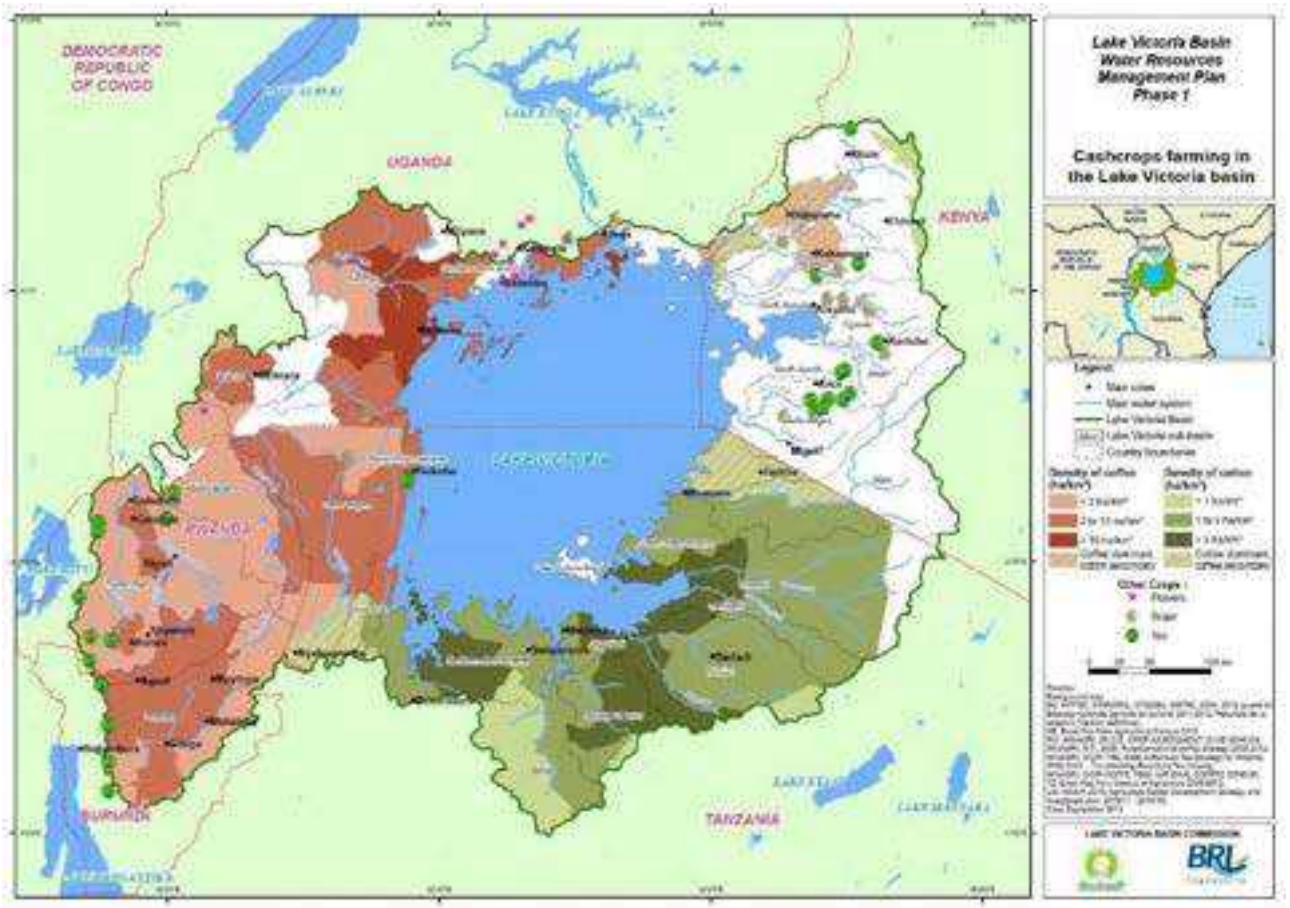


Figure 6-8. *Cash crop farming systems in the Lake Victoria Basin (LVBC & BRL, 2014)*

Productivity remains persistently low, with yield gaps of 50–70% relative to attainable yields under good agronomic and water-management practices. Maize yields, for example, typically range from 1–2 t/ha despite on-station potentials of up to 9 t/ha (Mulinge et al., 2016). These gaps reflect widespread soil degradation, nutrient depletion, and low adoption of improved technologies. Soil nutrient balances are strongly negative due to limited fertiliser use—constrained by cost, credit access, and input availability—and continuous nutrient mining from cropped fields (Namubiru-Mwaura et al., 2017; Ntinyari et al., 2022). As soil fertility declines, farmers increasingly expand cultivation onto marginal slopes, intensifying erosion and contributing to sediment delivery into rivers and Lake Victoria.

Mechanisation remains minimal, with most cultivation carried out manually and only limited use of ox-ploughs (ASARECA, 2024). Weak extension

services, insufficiently trained personnel, and limited outreach—particularly in erosion-prone and remote areas—further slow the adoption of improved seed, soil fertility amendments, and climate-smart practices (Swallow et al., 2002). These structural constraints are compounded by high post-harvest losses arising from poor storage, inadequate drying technologies, and weak market systems (Government of Kenya, 2019), which together reduce household food availability and waste the labour, nutrients, and water invested in production.

In the absence of irrigation, productivity is highly dependent on effective soil-moisture management. A range of practices—mulching to reduce evaporation, conservation tillage to improve infiltration, contour bunds and planting pits to retain runoff, and household-level rainwater harvesting for supplemental irrigation—have demonstrated benefits, especially under increasing climate variability (IWMI, 2009). Farmers across the basin face more erratic rainfall onset, more frequent mid-season dry spells, declining reliability of the long rains, and short bursts of high-intensity storms that accelerate erosion and damage young crops (Evans et al., 2020).

Rainfed agriculture is therefore constrained by a mutually reinforcing set of challenges: chronic nutrient depletion, severe soil erosion in densely settled highlands, inadequate access to inputs and extension services, and rising climate variability. Addressing these constraints requires integrated approaches that rebuild soil fertility, strengthen soil–water management, expand access to technologies and advisory services, and reduce post-harvest losses. Such investments offer substantial potential to enhance the resilience and productivity of the basin's dominant agricultural system and safeguard long-term food and livelihood security.

6.2.3 Irrigated Agriculture

Irrigation covers less than 5% of cultivated land in the Lake Victoria Basin (LVB), yet where it exists, it delivers substantially higher and more reliable yields—particularly for rice, vegetables, sugarcane, and other high-value crops. Irrigated rice systems (**Figure 6-8**) typically apply far higher fertiliser rates and achieve yields two to four times greater than rainfed production (Ntinyari et al., 2022).



Figure 6-9. *Farmers planting paddy rice in Ahero Irrigation Scheme, Kenya (Source: National Irrigation Authority, Kenya).*

Most existing irrigation is small-scale and concentrated in river valleys, wetlands, and shoreland depressions, while larger schemes—such as Tanzania's Bugwema system and Kenya's National Irrigation Board (NIB) rice schemes—provide structured support through credit, improved seed, and extension services.

The basin, however, is characterised by "**economic water scarcity**": water resources are available, but limited infrastructure constrains their productive use (FutureWater, 2008). The gap between potential irrigable land and the area actually equipped is substantial (see **Table 6-6).**

Table 6-6. Irrigation Potential and Area Equipped in LVB Partner States (national estimates).

Country	Irrigation Potential (ha)	Area Equipped (ha)	Year	Source
Burundi	–	21,430	~2000	FAO (2000)
Kenya	539,500	200,370	~2015–2022	FAO (2015a)
Rwanda	–	–	–	FAO (2015b)
Tanzania	2,300,000	363,500	2016 / 2022	FutureWater (2008); FAO (2016)
Uganda	–	–	–	FAO (2015b)

National datasets show wide disparities: Tanzania has an estimated 2.3 million ha of irrigable potential but only 363,500 ha equipped; Kenya has 539,500 ha of potential and just over 200,000 ha equipped; while Burundi reports only 21,430 ha equipped (FAO, 2000; FAO, 2015a; FAO, 2016). Basin-specific estimates vary widely—from FAO's conservative 660,000 ha to LVBC's higher estimates of 1.1–1.4 million ha—yet all indicate that only a small fraction of potential has been developed. Earlier basin-wide estimates identified only 20,000–36,000ha under irrigation in the early 2010s, underscoring the limited scale of current utilisation.

Large commercial estates dominate high-value irrigated production in sugarcane, tea, flowers, and increasingly rice (GRID-Arendal & LVBC, 2022). In Tanzania, nearly 30% of planted area on large-scale farms is irrigated, compared with only 3.5% among smallholders (NBS, 2025). These estates employ higher mechanisation levels, structured input provision, and integrated processing, resulting in better market integration and lower post-harvest losses than smallholder irrigation (Sulle & Smalley, 2016). By contrast, smallholder irrigation remains labour-intensive, relying on manual canal management and pump-fed systems with limited mechanised harvesting. The principal large-scale irrigation schemes in the LVB are summarised in **Table 6-7**.

"Large commercial estates dominate high-value irrigated production in sugarcane, tea, flowers, and increasingly rice (GRID-Arendal & LVBC, 2022). In Tanzania, nearly 30% of planted area on large-scale farms is irrigated,compared with only 3.5% among smallholders"

Table 6-7. **Large-scale irrigation schemes in he LVB (greater than 150 ha).**

No.	Country	Scheme	Irrigation Area (ha)	Water Source
1	Kenya	West Kano	910	Lake Victoria
2	Kenya	Ahero	1,050	Nyando River
3	Kenya	Southwest Kano	1,200	Lake Victoria
4	Kenya	Northwest Kano	800	Lake Victoria
5	Kenya	Amala Dam Irrigation	5,000	Unknown
6	Kenya	Ilooiterre Dam Irrigation	2,000	Unknown
7	Kenya	Kimira-Oluch Irrigation	1,574	Kimira-Oluch
8	Kenya	Lower Kuja Irrigation	22,800	Kuja River
9	Kenya	Nandi Forest Dam Irrigation	7,272	Unknown
10	Kenya	Nyando Dam Irrigation	3,000	Nyando River
11	Kenya	Kano Plain Irrigation	15,000	Lake Victoria
12	Kenya	Kiboho Dam Irrigation	1,500	Unknown
13	Kenya	Lower Nzoia Irrigation	10,470	Nzoia River
14	Kenya	Lower Sio Irrigation	6,600	Sio River
15	Kenya	Moi's Bridge Dam Irrigation	10,000	Nzoia River
16	Kenya	Upper Nzoia Irrigation	7,500	Nzoia River
17	Kenya	Yala Swamp Drainage & Irrigation	4,600	Yala River
18	Kenya	Dominion Farms	1,480	Yala River
19	Kenya	Bunyala	700	Nzoia River
22	Tanzania	Maliwanda	220	Grumeti River
23	Tanzania	Nyatwali	208	Grumeti River
24	Tanzania	Mwasubuya	165	Simiyu River
25	Tanzania	Mahiga Dam Scheme	300	Magogo River
26	Tanzania	Igongwa	220	Magogo River
27	Tanzania	Irienyi	220	Mori River
28	Tanzania	Rabour	450	Mori River
29	Tanzania	Kagera sugar estate	1,200	Kagera river
30	Burundi	Upper Ruvubu	773	Ruvubu River
31	Uganda	Kakira sugar	6,800	Lake Victoria

Supporting these irrigation schemes and broader water supply needs across the basin are several large-scale reservoirs (greater than 1 million cubic metres), concentrated primarily in Kenya and Tanzania (**Table 6-8**). These storage facilities serve multiple purposes—water supply, hydroelectric power generation, and irrigation—with notable examples including Kenya's Moiben Dam (18 million m³) in the Nzoia catchment and Tanzania's Nyankanga Dam (9.95 million m³) serving the Southern Shore Streams. A transformational addition to this infrastructure is Rwanda's Nyabarongo II Multipurpose Dam in the Kagera catchment, currently under construction with commissioning expected in January 2026. With a reservoir capacity of 843 million m³ and designed to irrigate 20,000 ha of farmland, Nyabarongo II will be by far the largest storage facility in the Lake Victoria Basin, representing a major step forward in water security and agricultural productivity for the region. Despite this development, storage infrastructure distribution remains uneven across the basin, with Uganda notably lacking large-scale reservoirs despite its extensive shoreline and water resources.

Table 6-8. Large-scale reservoirs (greater than 1 million cubic metres) in the LVB.

No.	Country	Catchment	name	Purpose	Status	Capacity (MCM)
1	Tanzania	Grumeti	Manchuria	Water supply	Operational since 2012	3.5
2	Tanzania	Simiyu	New Sola Dam	Water supply	Operational	7.4
3	Tanzania	Southern Shore Streams	Nyankanga	Water Supply	Operational	9.95
4	Kenya	Sondu	Sondu Miriu	HEP/Irrigation	Operational	1
5	Kenya	Gucha-Migori	Gogo Falls	HEP/Irrigation	Operational since 1956	
6	Kenya	Nzoia	Moiben	Irrigation/water supply	Operational	18
7	Kenya	Nzoia	Klipkarren	Irrigation/water supply	Operational	3
8	Kenya	Nzoia	Ellegirini	Irrigation/water supply	Operational since 1987	2
9	Kenya	Yala	Kesses	Irrigation/water supply	Operational	1
10	Rwanda	Kagera	Nyabarongo II Multipurpose Dam	Irrigation/water supply/ HEP	Under construction (2025)	846

Despite its higher productivity, irrigated agriculture faces significant technical, economic, and governance challenges. Most existing schemes rely on surface irrigation—still used for around 70% of irrigated land in Kenya—resulting in high conveyance losses and low water-use efficiency (FAO, 2015a). Poorly maintained canals and aging infrastructure reduce water delivery reliability, while siltation from upstream catchment degradation further constrains performance. Runoff from fertilisers and pesticides contributes to eutrophication and pollution of rivers and the lake, and inefficient surface irrigation increases risks of waterlogging and salinisation, especially in alluvial plains.

Under-investment in infrastructure, weak operation and maintenance, and insecure land tenure continue to hinder expansion and modernisation. National master plans for Kenya, Tanzania, and Uganda collectively target more than 380,000 ha for development, yet only

about one-third of this area has been validated as technically feasible and investment-ready by the Nile Basin Initiative (NBI, 2020). Socio-economic barriers—including low farm-gate prices, limited credit access, and the high cost of pumps, fertilisers, and energy—further constrain smallholder uptake of improved irrigation technologies.

Water allocation pressures are also expected to intensify. Agriculture already accounts for the majority of consumptive water use in the basin, and demand will rise with population growth and future irrigation expansion. Without water-saving technologies—such as sprinkler, drip, and improved canal lining—there is a risk of increased scarcity in some hotspots, particularly along the densely populated southern shores by mid-century.

Environmental sustainability remains a central concern. Wetland degradation, uncontrolled abstractions, drainage of floodplains, and catchment erosion all undermine the ecological integrity of the basin and reduce long-term water availability. Large-scale irrigated estates are also notable point sources of agrochemical pollution, with documented cases of runoff containing banned substances (GRID-Arendal & LVBC, 2022).

Overall, irrigation in the LVB offers major opportunities for boosting productivity and enhancing climate resilience, but realising this potential requires substantial modernisation, stronger water governance, targeted investment in efficient technologies, improved catchment management, and measures that enable smallholders to benefit more equitably from irrigation development.

6.2.4 Livestock Water Use

Livestock production is a major economic and social pillar across the Lake Victoria Basin (LVB). Beyond supplying meat, milk, hides, and skins, the sector contributes directly to household income, asset accumulation, and drought-coping capacity. For many rural households—particularly in semi-arid zones of Tanzania, Kenya, and Uganda—livestock remain the most valuable productive asset and the backbone of pastoral and agro-pastoral livelihoods. As such, the reliability of livestock water supplies is central to both economic stability and food security in the basin.

The basin hosts substantial livestock populations, dominated by cattle, goats, sheep, pigs, and poultry. These numbers determine water demand and grazing pressure and influence land-use patterns. National census data (**Table 6-9**)—though variable in recency—continue to provide the most credible estimates.

Table 6-9. Selected Livestock Population Estimates in LVB Partner States.

Country	Livestock Type	Population / Households	Year	Source
Uganda	Cattle	14.5 million	2021	UBOS (2024a)
Uganda	Goats	17.4 million	2021	UBOS (2024a)
Uganda	Sheep	4.4 million	2021	UBOS (2024a)
Kenya	Cattle	18 million	2024	KNBS (2024)
Kenya	Goats	27.7 million	2024	KNBS (2024)
Kenya	Sheep	17 million	2024	KNBS (2024)
Tanzania	Cattle	36.6 million	2024	World Bank (2024)

Note: *Rwanda and Burundi lack livestock datasets of comparable reliability.*

The most comprehensive basin-specific estimates of livestock population come from studies by the Nile Basin Initiative (NBI) and its partners, which disaggregate national data to the basin-portion level. These studies (**Table 6-10**) estimated 15.6 million cattle, 8.7 million goats, and 3.8 million sheep in the basin. However, this data is over a decade old.

Table 6-10. *Estimated Livestock Populations within the Lake Victoria Basin Portion of Riparian Countries (Peden et al., 2012)*

Country	Cattle (Millions)	Goats (Millions)	Sheep (Millions)
Burundi	0.2	0.46	0.1
Kenya	4.2	1.58	1.4
Rwanda	0.7	0.83	0.2
Tanzania	5.5	2.89	0.8
Uganda	5.0	2.97	1.3
TOTAL (LVB)	**15.6**	**8.73**	**3.8**

The basin experiences distinct wet and dry seasons, which strongly influence livestock water access. During dry seasons, many valley tanks, pans, shallow wells, and streams recede or dry out. Simultaneously, pasture biomass decreases, forcing herders—especially pastoralists in Kenya, Tanzania, and Uganda's cattle corridor—to move longer distances in search of water and grazing.

This seasonal mobility carries several interconnected consequences. As herds travel longer distances in search of water and pasture, productivity declines, reflected in reduced milk yields and slower weight gain. Mortality rates also rise, particularly among calves and weaker animals unable to withstand the stress of movement. Concentration of animals at the few remaining water points increases exposure to infectious and tick-borne diseases, while the heightened labour burden—especially long daily trips to water sources—falls disproportionately on women and children, deepening their vulnerability during the dry season.

Water requirements vary widely—cattle typically require 20–50 litres per head per day, goats 2–5 litres, and poultry considerably less. In hotter lowland zones, water demand can be substantially higher due to heat stress.

Infrastructure for livestock water use includes valley tanks, boreholes, protected springs, watering troughs, and rainwater harvesting systems, often complemented by animal-health facilities such as dips and cattle crushes that support integrated herd management. The effectiveness of these systems is often undermined by inadequate maintenance that results in recurring breakdowns of boreholes and pumps, chronic under-investment in areas with high livestock densities, and weak governance arrangements where water points are shared among multiple clans or livelihood groups, leading to unreliable service and heightened competition over access.

"During dry seasons, many valley tanks, pans, shallow wells, and streams recede or dry out. Simultaneously, pasture biomass decreases, forcing herders—especially pastoralists in Kenya, Tanzania, and Uganda's cattle corridor—to move longer distances in search of water ....."



Figure 6-10. *Masai youth grazing cattle in the Masai Mara National Reserve, Kenya. (Source: www.grida.no Peter Prokosch)*

6.3: Fisheries and Aquaculture

Section 6.3 analyses how fisheries and aquaculture underpin livelihoods, nutrition, and economic development in the Lake Victoria Basin, while increasingly mirroring wider ecological and governance stresses. It traces the shift from a diverse artisanal fishery to an export-oriented, biologically stressed capture fishery, assesses the rapid rise of aquaculture (especially cage culture), and examines how overfishing, pollution, weak institutions, and gendered inequalities shape outcomes along the value chain. The section concludes by considering pathways toward a more sustainable blue economy that balances capture and culture fisheries and strengthens the resilience of riparian communities.

6.2.1 Introduction and Context

Lake Victoria supports the world's second-largest inland fishery, with an estimated annual beach value of USD 1.1 billion (Abelti, 2024). Export revenues—dominated by Nile perch—amount to roughly USD 300 million per year. Although national accounts record modest GDP contributions (2.6% in Uganda, 2.5% in Tanzania, 0.5% in Kenya), these understate the sector's true economic footprint because extensive domestic and regional trade remains informal and unrecorded.

The sector supports 3–4 million people, including more than 234,000 active fishers (**Table 6-11**) (LVFO, 2020; Biginagwa et al., 2016). Beyond fishing, hundreds of thousands depend on associated value-chain activities such as trading, processing, transport, and boat building. Fish is a cornerstone of local diets and micronutrient intake, especially for the basin's low-income households, who rely heavily on affordable species such as *Dagaa* (*Rastrineobola argentea*). Meanwhile, the export-oriented Nile perch industry often competes with local food-security needs, reinforcing longstanding tensions in resource allocation (Abila, 2003). Fishing also remains an integral part of the cultural identity of riparian communities, even as the shift from artisanal to commercialized fisheries continues to reshape traditional practices and institutions.

Table 6-11. *Key Economic and Livelihood Indicators of LVB Fisheries (c. 2020–2021)*

Metric	Value / Estimate	Source
Total annual value (beach price)	~USD 1.1 billion (2021); ~$600 million annual income from fisheries	Abelti (2024); Lake Victoria Fisheries Organization (LVFO), 2022
Annual export earnings	~USD 300 million	LVFO (n.d.-a)
Livelihoods supported	3–4 million people	Biginagwa et al. (2016)
Direct employment (fishers)	>234,000 (2020)	LVFO (2020)
GDP contribution	2.6% (Uganda); 2.5% (Tanzania); 0.5% (Kenya)	LVFO (2007)
Kenya – Value of Fisheries	Sh39.6 billion (~$300 million) total value of fish production; Sh14.5 billion (~$110 million) from inland capture (mostly Lake Victoria	Kenya Fisheries Service (KeFS), 2024
Tanzania – Value of Fisheries	Sh520.87 billion (~$206.6 million) from fish exports (largely from Lake Victoria)	Ministry of Livestock and Fisheries, (2025).
Uganda – Value of Fisheries	US$ 117.7 million (Fiscal Year 2024/2025)	KPMG (2025)

Sector productivity is entirely dependent on the health of the basin's interconnected aquatic ecosystems. As detailed in Chapters 3, Lake Victoria's shallow morphology and extensive network of rivers, wetlands, and satellite lakes create vital spawning and nursery habitats that sustain fish stocks (Biginagwa et al., 2016). These ecosystems are highly sensitive to climatic variability and catchment dynamics, making them vulnerable to degradation.

Fisheries and aquaculture face a convergence of ecological and socio-economic pressures:

1. **Ecosystem Degradation:** Pollution from agriculture, industry, and rapidly expanding urban centres drives eutrophication, algal blooms, and hypoxic zones, degrading critical habitats and reducing fish productivity (Abelti, 2024; Biginagwa et al., 2016).
2. **Climate Change:** Rising temperatures, variable lake levels, and more frequent extreme weather events alter thermal stratification and increase anoxic conditions, threatening both fish stocks and fisher safety (Odongo & Obwanga, 2023).
3. **Excessive Fishing Pressure:** Population growth, economic incentives, and weak enforcement contribute to chronic overfishing and widespread illegal, unreported, and unregulated (IUU) fishing, placing stress on stocks already near or beyond biological limits.

6.3.2 Capture Fisheries

6.3.2.1 Structure and Trends of the Capture Fishery

The wild capture fishery of Lake Victoria has shifted from a diverse, artisanal, multi-species system to a high-volume, commercially oriented fishery dominated by three species. This transformation has generated substantial economic benefits but has also driven the resource into a state of acute biological and governance stress.

Figure 6-11 shows that total annual catch rose from about 0.73 million tonnes in 2000 to over 1.3 million tonnes by 2024. However, this growth masks a major shift in species dominance. The early 2000s were the tail end of the Nile Perch export boom, but intensifying fishing pressure, declining size at maturity, and widespread use

of illegal gears led to a progressive reduction in Nile Perch biomass (Mkumbo & Marshall, 2015). In parallel, *Rastrineobola argentea* (Dagaa) expanded rapidly—an ecological response to reduced predation and increasing nutrient loads—becoming the major driver of total volume growth after 2009 (Kolding et al., 2019; LVFO, 2022).

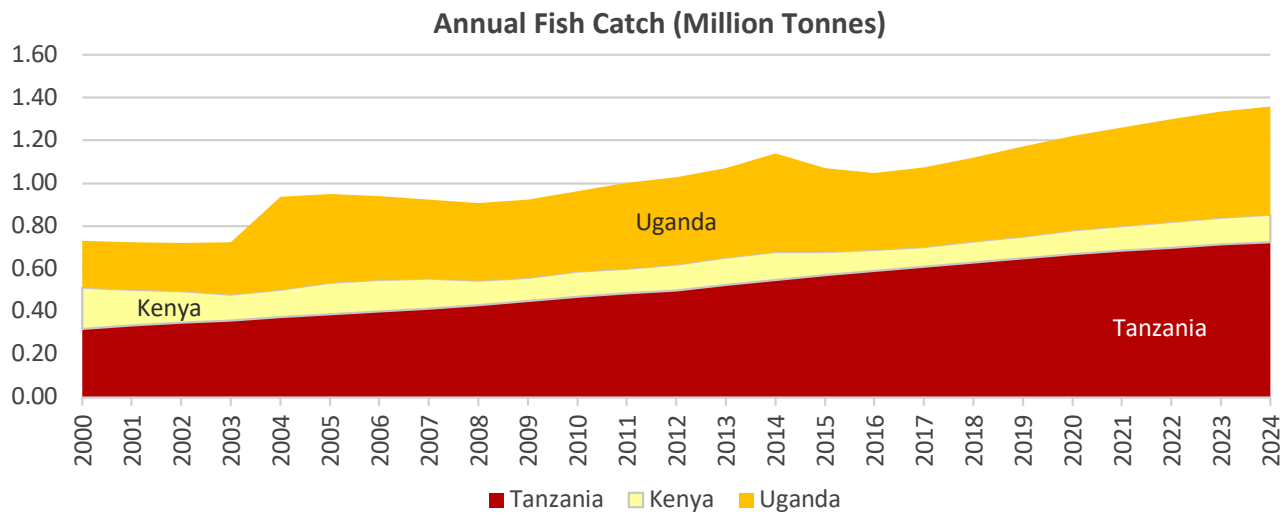


Figure 6-11. *Annual fish catch (million tonnes) from Lake Victoria in the LVB Partner States. (Sources: **Kenya**: (KNBS, 2002; KNBS, 2014; KNBS, 2019; KNBS, 2024; Schubert et al., 2021); **Tanzania**: FAO, 2023; LVFO, 2005; LVFO, 2007; LVFO, 2022; MLF, 2014; MLF, 2017; MLF, 2020; **Uganda**: LVFO, 2007; LVFO, 2017; LVFO, 2022; Mkumbo & Marshall, 2015; NaFIRRI, 2007; Nunan et al., 2018; UBOS, 2002; UBOS, 2006; UBOS, 2010; UBOS, 2014; UBOS, 2019).*

Species-level data from **Table 6-12** provides a critical snapshot of this transition: by 2021, the catch was dominated by Nile Perch (53%), Dagaa (23.2%), Nile Tilapia (7.2%), Haplochromines (1.7%), and Other species including catfishes (14.8%). These proportions capture the rebalancing of the lake's trophic structure, illustrating both the persistence of Nile Perch as the primary economic species and the expanding role of Dagaa in sustaining total biomass removal.

Table 6-12. *Annual Fish Catch (tonnes) from Lake Victoria by Species and Country (2021) (Source: LVFO (2022), CAS 2021 synthesis)*

Species	Uganda	Tanzania	Kenya	Total	% of Total
Nile perch (*Lates niloticus*)	164,340	280,404	158,844	603,588	53.0%
Dagaa (*Rastrineobola argentea*)	63,732	144,324	56,616	264,672	23.2%
Tilapia (*Oreochromis niloticus*)	54,180	16,104	12,240	82,524	7.2%
Haplochromines	9,756	6,720	3,384	19,860	1.7%
Others	144,640	9,384	14,628	168,652	14.8%
Total	**436,648**	**456,936**	**245,712**	**1,139,300**	**100.0%**

Country-specific dynamics further shape these basin-wide trends. Uganda's strict enforcement through the Fisheries Protection Unit (2017–2020) caused an immediate drop in recorded landings but resulted in measurable recovery of Nile Perch biomass and improved size structure by 2019–2021 (LVFO, 2022; Nunan et al., 2018). Kenya, by contrast, experienced a long-term decline in its wild capture fishery, driven by habitat degradation and reduced water exchange in the Winam Gulf (Njiru et al., 2008), with recent stabilisation largely attributable to cage aquaculture rather than stock recovery (Aura et al., 2020). Tanzania remains the volume leader, benefiting from extensive deep-water habitats that support large Dagaa shoals and buffer against localised depletion (LVFO, 2022). Together, these dynamics explain the lake's capacity to maintain high total landings despite persistent pressure on higher-value species.

Economic trends show a more variable and decoupled pattern. As illustrated in **Figure 6-13**, beach value increased from about USD 600 million in the early 2000s to over USD 1.2 billion by the mid-2020s (LVFO, 2022), even in years when biomass stagnated or Nile Perch landings fell. This divergence reflects rising unit prices for Nile Perch fillets, the emergence of the lucrative fish maw trade (Bagumire et al., 2018), and the growing importance of Dagaa in regional feed markets. Enforcement-driven improvements in the size structure of Uganda's Nile Perch catches further boosted export values despite reduced tonnage. Conversely, climate shocks—most notably the 2020–2021 flooding that submerged drying racks and landing sites—suppressed realised value in some years despite adequate biological availability.



Figure 6-12. *Ms. Jackie Tukahirwa, Resident District Commissioner of Entebbe setting on fire illegal fishig gear and impounded immature fish in October 2023. (Source: nexusmedia.ug)*.

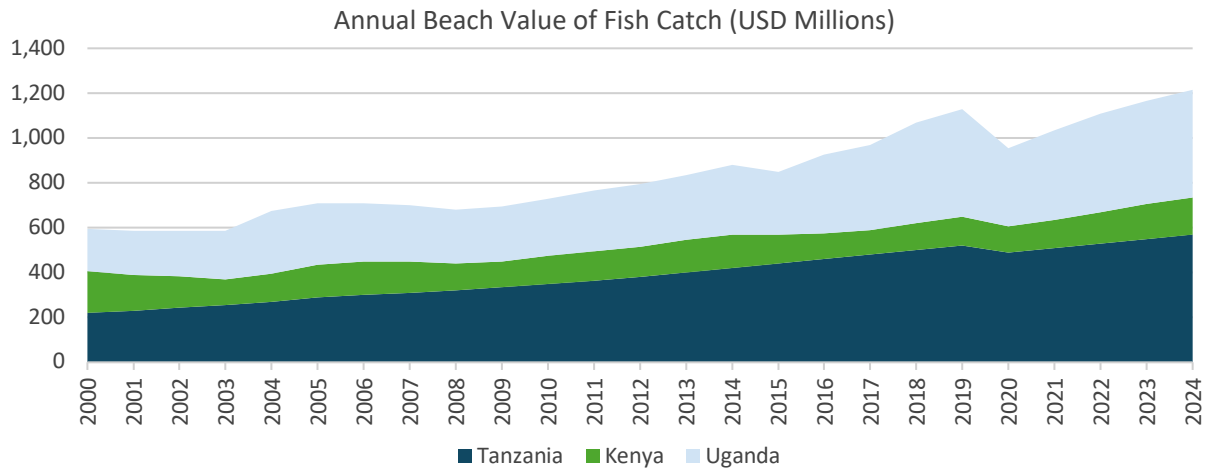


Figure 6-13. *Annual beach value of fish catch (USD millions) from Lake Victoria in the LVB Partner States. (Sources: **Kenya**: (KNBS, 2002; KNBS, 2014; KNBS, 2019; KNBS, 2024; Schubert et al., 2021); **Tanzania**: FAO, 2023; LVFO, 2005; LVFO, 2007; LVFO, 2022; MLF, 2014; MLF, 2017; MLF, 2020; **Uganda**: LVFO, 2007; LVFO, 2017; LVFO, 2022; Mkumbo & Marshall, 2015; NaFIRRI, 2007; Nunan et al., 2018; UBOS, 2002; UBOS, 2006; UBOS, 2010; UBOS, 2014; UBOS, 2019).*

Taken together, the 2000–2024 period reveals a fishery in adaptive transition: high aggregate volumes maintained through a shift toward lower-value species and aquaculture, juxtaposed with fluctuating economic returns shaped by regulation, market forces, and climatic variability. The contrasting trajectories of Nile Perch and Dagaa underscore a central management challenge: sustaining economic benefits while restoring ecological integrity in a system approaching its biological limits (LVFO, 2022; Kolding et al., 2014).

The data presented in Figure 6-11 and Figure 6-12 were compiled from a harmonised synthesis of multiple authoritative sources across the three Lake Victoria riparian states. Annual catch volumes draw primarily on the Regional Catch Assessment Surveys (CAS) coordinated by the Lake Victoria Fisheries Organization (LVFO), complemented by national fisheries statistics reports issued by the ministries responsible for fisheries in Kenya, Tanzania, and Uganda, and by annual statistical abstracts published by the respective national statistical offices.

To ensure comparability of economic trends across countries and over time, the beach value of fish catch was converted from local currencies into USD using prevailing annual exchange rates, sourced from the central banks of the three countries. This standardisation addresses inflation and currency fluctuations, enabling a consistent basin-wide analysis of value.

Beyond the main lake, rivers, satellite lakes, and wetlands also sustain important artisanal fisheries and act as refugia for native species extirpated or depleted in Lake Victoria proper (Biginagwa et al., 2016; Masese et al., 2025).

Mass fish kills—affecting both cage aquaculture and wild stocks—have become increasingly visible in recent years. Investigations attribute these events to the interaction of eutrophication and climate variability: nutrient-driven algal blooms deplete oxygen as they decompose, while stronger thermal stratification associated with warming traps hypoxic water at depth. Wind-driven upwelling can then bring this oxygen-poor water into contact with fish, causing sudden mortalities (Odongo & Obwanga, 2023). These events highlight the tight coupling between land-based pollution, climate change, and fishery resilience.

6.3.2.2 Effort, Gear, Gender Dynamics and Value Chain Performance

The capture fishery is marked by pronounced gender inequities. Around 80% of men in the sector are engaged in capture, while most women are concentrated in lower-paid, informal post-harvest roles such as processing and trading (Wanyama et al., 2018). Limited access to capital, assets, and decision-making power exposes many women to exploitative arrangements, including transactional "sex-for-fish" practices documented in sections of the basin (Owuor, 2022). These inequities not only undermine human rights but also weaken the overall resilience and inclusiveness of the value chain.

The single most important driver of stress on the fishery is the rapid escalation in fishing effort. Between 2000 and 2020, the number of fishers and boats roughly doubled, while the share of motorized vessels tripled and the number of hooks in long-line fisheries quadrupled (Figure 6-14). This "effort creep" has been accompanied by the proliferation of both legal and illegal gears. Legal gears include larger-mesh gillnets, long lines, and Dagaa seines, but illegal gears—beach seines, trawls, cast nets, and undersized gillnets and hooks—remain widespread (Balirwa et al., 2003). This expansion in effort and destructive gears has driven down catch-per-unit-effort and truncated size structures in key stocks, particularly Nile perch (Nyamweya et al., 2020).

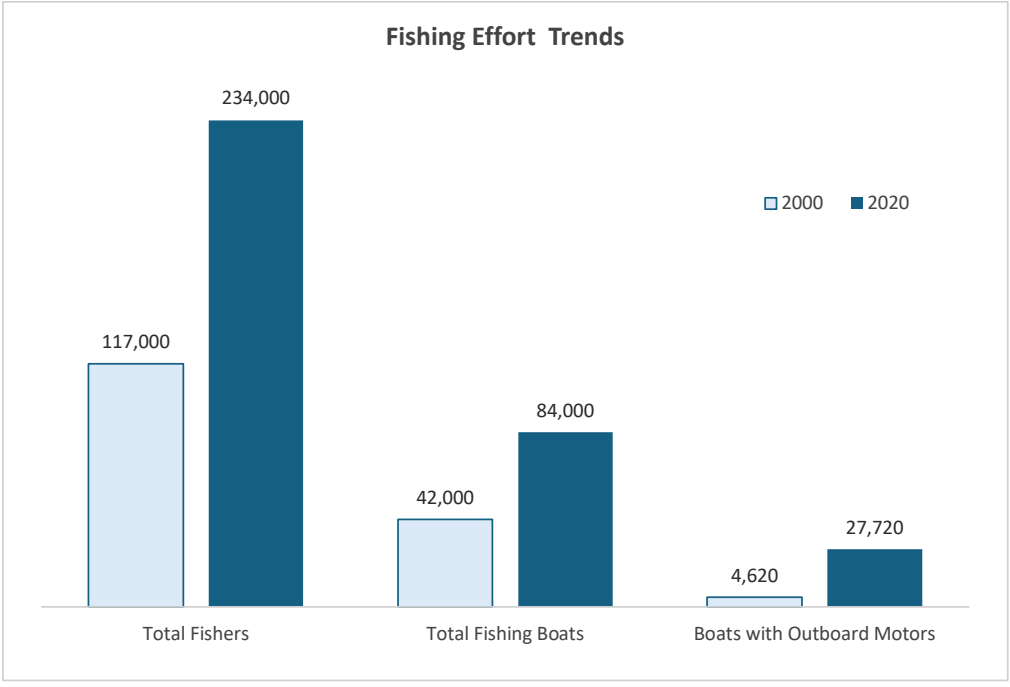


Figure 6-14. *Trends in Fishing Effort (Fishers and Vessels) in Lake Victoria (2000–2020) (Source: Synthesized from LVFO, 2020, 2021;)*

Lake Victoria's capture fishery supplies local, regional, and international markets, but value is heavily eroded by post-harvest losses (PHL). Losses are particularly acute in the Dagaa fishery, where 30–40% of the catch is estimated to be lost or severely degraded due to drying on bare ground and limited hygiene (Odoli et al., 2019). Inadequate cold-chain infrastructure at landing sites further constrains quality for all species.

Simple, low-cost solutions offer substantial gains. Raised drying racks significantly reduce contamination and improve product quality, while solar-powered, pay-as-you-go cold storage pilots in western Kenya and the broader region demonstrate promising reductions in spoilage and income gains for small-scale operators (GIZ, 2024; PREO, 2024).

6.3.2.3 Over-Exploitation, IUU Fishing, and Habitat Stress

The capture fishery is characterized by chronic over-exploitation and pervasive Illegal, Unreported and Unregulated (IUU) fishing. Estimates suggest that 40–60% of fishing on Lake Victoria is IUU, involving banned gear, fishing in closed areas, and harvesting of undersized fish (IOM, 2024). Stock assessments and size-structure data indicate that key stocks—particularly Nile perch—are heavily fished, with mean sizes below maturity, implying systematic harvesting of juvenile "capital" rather than reproductive "interest" (Balirwa et al., 2003; Nyamweya et al., 2020).

At the same time, shoreline degradation, wetland conversion, and nutrient and pollutant loading from the catchment have degraded critical spawning and nursery habitats (Biginagwa et al., 2016; Masese et al., 2025). The invasive water hyacinth further disrupts fisheries by blocking access and landing sites, even as dense mats may create temporary refuges from fishing in some areas (Villamagna & Murphy, 2010; Biginagwa et al., 2016).

6.3.2.4 Governance, Co-Management, and Enforcement Gaps

Regionally, the **Lake Victoria Fisheries Organization (LVFO)**—a specialized institution of the EAC—coordinates scientific assessments and management through instruments such as the Fisheries Management Plans and the Regional Plan of Action to Prevent, Deter and Eliminate IUU Fishing (LVFO, 2016). However, the effectiveness of this framework is undermined by weak domestication and enforcement at national level, with many agreed measures (e.g., gear controls, spatial closures) only partially implemented (Stop Illegal Fishing, 2016).

At the local level, **Beach Management Units (BMUs)** are the principal co-management institutions, mandated to involve communities in monitoring and enforcement. In practice, BMUs often lack legal authority, resources, and incentives to regulate powerful local interests, leading to limited impact on illegal fishing and compliance (Luomba, 2013).

6.3.3 Aquaculture

Aquaculture in the Lake Victoria Basin: Status, Trends, and Constraints

Aquaculture has grown rapidly across the LVB (**Figure 6-15**) as countries seek to offset declining capture fisheries, meet rising urban demand for affordable protein, and generate rural employment. The expansion—driven especially by cage culture and dominated by Kenya has been dramatic, but it has proceeded faster than regulation, environmental safeguards, and input supply systems can adapt, creating a mix of opportunities and escalating risks (KMFRI, 2022).

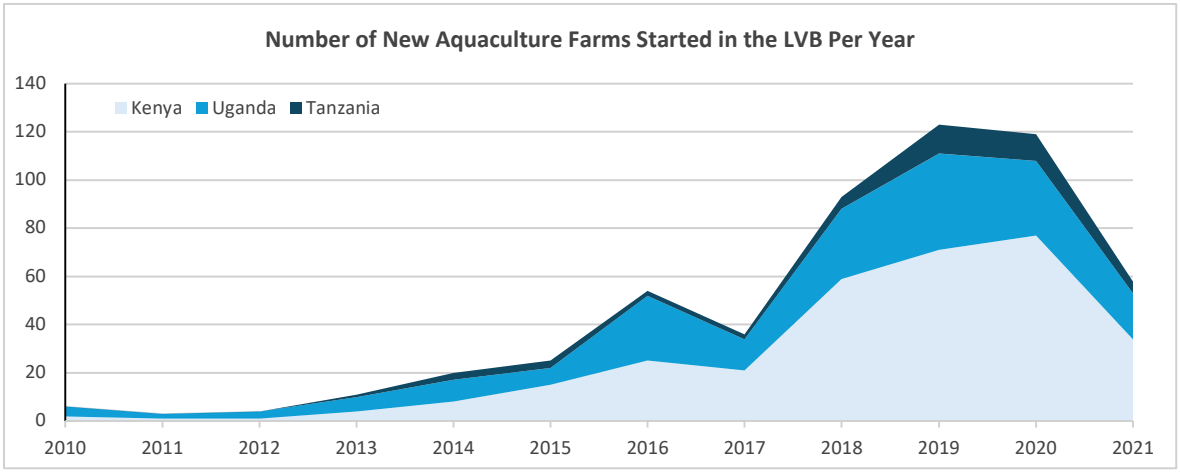


Figure 6-15. *The increase aquaculture farms in the Lake Victoria Basin. (Source: LAT, 2022)*

Regional aquaculture output has increased substantially. Uganda now leads with 138,558 tonnes in 2021 (FAO, 2023). Tanzania reported 106,482 tonnes, though ~77,000 tonnes of this is seaweed; freshwater finfish production is far smaller (FAO, 2023). Kenya's most recent verified figure is 33,289 tonnes (KeFS, 2024). Freshwater finfish production continues to rely primarily on Nile tilapia and African catfish (Mboya & Ouko, 2023).



Figure 6-16. *A cage fish farm on Lake Victoria. (Source: Busia Country Government, Kenya).*

Tilapia and African catfish remain the backbone of freshwater aquaculture, supplemented by a small but growing ornamental sector in Kenya. The most striking trend is the rise of cage culture: an FAO census identified a total of 8,024 cages installed on Lake Victoria, distributed as 6,169 in Kenya, 1,809 in Uganda and 46 in Tanzania (FAO, 2022). The strong geographic clustering in sheltered bays, especially Winam Gulf and parts of the Uganda shoreline, has intensified localised ecological pressures.

Pond aquaculture remains widespread but low-input and low-productivity, with associated risks of habitat degradation and species escape. Cage

culture is commercially oriented and capital-intensive but depends on reliable input supply chains.

Two major bottlenecks constrain performance. First, fingerling supply remains far below demand; Uganda alone requires an estimated 2.5 billion high-quality fingerlings each year to meet national aquaculture targets, a level of production that current hatchery capacity cannot support (Mwanja et al., 2022). Second, feed accounts for over 50% of total production costs, leaving farmers highly exposed to feed price volatility and eroding profitability across the sector (Kaminski et al., 2025). These constraints are compounded by weak cold-chain and diagnostic infrastructure, which further limit production efficiency and undermine effective disease management.

Regulatory capacity has not kept pace with growth. Despite adoption of the EAC Cage Fish Farming Policy (2021), enforcement is limited. In Kenya, 76.7% of cage farmers did not consult environmental or fisheries authorities before installation (KMFRI, 2022; Njiru et al., 2018). Similar gaps exist in Uganda (LVFO, 2021).

The rapid expansion of cage aquaculture in Lake Victoria is generating significant environmental and social risks. Intensive feeding releases nutrient-rich waste that accelerates eutrophication and contributes to localised hypoxia in sheltered bays (Okechi et al., 2022). These conditions, combined with climate-driven stratification, have led to recurring mass mortality events, with 44% of farms reporting major fish kills in 2022–2023 (Abelti, 2024; Odongo & Obwanga, 2023). Open-exchange cages also heighten disease and parasite transmission between farmed and wild stocks (Cornell University et al., 2025). Human health concerns are mounting, as mercury concentrations of up to 335,000 ng/g dry weight have been detected in fish from mining-impacted areas (Oyege et al., 2025). Social tensions are emerging where cages impede access to fishing grounds and navigation routes.

These risks compound structural constraints that continue to limit sectoral performance. High feed and fingerling costs, limited access to credit, and weak technical capacity all undermine profitability and resilience (Kaminski et al., 2025; Mwanja et al., 2022; Aura et al., 2022). Farmers also remain exposed to environmental shocks such as storm damage and episodic hypoxia (Abelti, 2024). Together, these challenges highlight the need for stronger regulation and targeted investment to support sustainable aquaculture development.

Environmental and ecosystem impacts of cage fish farming on Lake Victoria

Cage fish farming has expanded rapidly across Lake Victoria as a strategy to supplement declining wild fisheries and enhance regional food security. While cage aquaculture can reduce direct fishing pressure on wild stocks, it operates as an open system, allowing wastes and biological interactions to pass freely between farmed fish and the lake. In an already eutrophic and stressed system such as Lake Victoria, this introduces important risks for water quality and ecosystem health if growth is not carefully planned and regulated (FAO, 2018; LVFO, 2018).

- **Impacts on water quality:** The most significant water-quality impact of cage fish farming is nutrient enrichment from uneaten feed and fish excreta. Nitrogen and phosphorus released directly into the water column and underlying sediments increase the risk of localized eutrophication, particularly in semi-enclosed bays and gulfs with weak flushing (Wu, 1995; Nixon, 2009). In Lake Victoria, where nutrient inputs from catchment runoff, wastewater, and atmospheric deposition are already high, cage-derived nutrients can further intensify algal blooms, including toxin-producing cyanobacteria.

  A closely linked impact is oxygen depletion. The microbial decomposition of organic wastes beneath and around cages increases oxygen demand, reducing dissolved oxygen concentrations, especially at night and during stratified conditions. Studies from Lake Victoria have documented localized hypoxia and benthic oxygen depletion in high-density cage-farming areas, increasing the risk of fish stress and episodic fish kills (Munguti et al., 2005; Kashindye et al., 2015).

Cage farming can also alter local water chemistry and clarity. Accumulation of organic matter may elevate ammonia concentrations near cages, while suspended waste particles increase turbidity in poorly flushed areas, reducing light penetration and affecting primary production dynamics (Wu, 1995).

- **Impacts on ecosystem health:** Cage fish farming exerts strong pressure on benthic habitats. The deposition of feed and faeces beneath cages leads to organic enrichment of sediments, favouring pollution-tolerant species and reducing benthic biodiversity. In Lake Victoria, shifts toward dominance by tolerant macroinvertebrates such as chironomids have been observed beneath and downstream of cages, indicating ecological degradation and altered nutrient cycling (Munguti et al., 2005).

Increased nutrient availability can also drive food-web alterations. Enhanced phytoplankton growth—particularly cyanobacteria—reduces food quality for zooplankton and can increase the frequency of harmful algal blooms, with implications for fisheries productivity, ecosystem resilience, and human health (Nixon, 2009; Tlusty et al., 2019).

High stocking densities in cages increase the risk of disease and parasite amplification, with cages acting as focal points for pathogen proliferation. These pathogens can spread to wild fish populations, particularly where farms are clustered and biosecurity measures are weak (FAO, 2018). In addition, escape of farmed fish, mainly Nile tilapia, may lead to competition with wild stocks and genetic dilution through interbreeding, potentially reducing the resilience of native populations (FAO, 2018).

Most environmental impacts of cage fish farming are localized, typically occurring within tens to hundreds of metres of cages. However, cumulative effects become significant where cage density is high, farms are concentrated in sheltered bays and gulfs, or regulatory oversight is weak (LVFO, 2018). In Lake Victoria—already affected by basin-wide eutrophication, hypoxia, and biodiversity loss—uncontrolled expansion of cage aquaculture could intensify existing water-quality and ecosystem-health challenges. This underscores the importance of spatial planning, carrying-capacity assessments, strict feed and stocking controls, and sustained environmental monitoring to ensure cage fish farming contributes to food security without undermining the ecological integrity of the lake.

6.3.4 Synthesis: Challenges, Opportunities, and Strategic Outlook

Overview

The fisheries and aquaculture sector of the Lake Victoria Basin is at a decisive turning point. The capture fishery continues to operate in a state of biological overshoot, sustained by excessive and largely illegal fishing effort that has reduced many stocks below reproductive levels (LVFO, 2020). At the same time, the rapid expansion of cage aquaculture—often promoted as the sector's remedy—is generating new pressures, including nutrient loading, eutrophication, disease outbreaks and, increasingly, risks to human health from contaminant bioaccumulation (Okechi et al., 2022; Odongo & Obwanga, 2023; Oyege et al., 2025).

These crises are mutually reinforcing. Catchment pollution, already a major driver of eutrophication, interacts with nutrient discharge from cages to intensify hypoxia and episodic mass fish kills (Okechi et al., 2022; Odongo & Obwanga, 2023). Socio-economic pressures—rapid population growth, persistent poverty, and limited livelihood alternatives—continue to push fishers into IUU practices, undermining stock recovery efforts (LVFO, 2020; IOM, 2024). The result is a complex cycle in which both capture fisheries and aquaculture are simultaneously threatened by ecological decline.

Balancing Capture and Culture

Aquaculture can play a central role in easing

pressure on wild stocks, but only if transformed into a regulated and environmentally responsible industry (LVFO, 2016; LVFO, 2021). This requires strict implementation of the EAC Cage Fish Farming Policy, spatial planning of cage sites, effective environmental monitoring, and enforcement of national regulations. In parallel, the capture fishery must be reduced to sustainable effort levels through strengthened Monitoring, Control and Surveillance (MCS), coordinated transboundary enforcement, and revitalised co-management.

The Blue Economy Pathway

The region's strategic shift toward a Blue Economy—as articulated by LVBC and LVFO—offers a promising framework for transition from volume-driven exploitation to value-driven, sustainable growth (LVBC, 2021; LVFO, 2022). Significant opportunities lie in value addition, particularly in processing fish maws, skins, and frames, which remain underutilised despite strong market potential (Aura et al., 2022). A robust cold chain could dramatically reduce the current 30–40% post-harvest losses, especially for Dagaa and Nile perch (GIZ, 2024; PREO, 2024). Diversification into fisheries-related ecotourism provides additional non-extractive livelihood opportunities.

Innovation and Technology

Innovation offers important pathways for reform. Digital tools are improving price transparency and market access for fishers (Simiyu et al., 2025), while IoT-enabled monitoring in cages enhances early detection of oxygen stress and disease. These technologies also hold social benefits: enabling women to own and monitor aquaculture units can help shift power relations within the value chain. Addressing critical input bottlenecks will require investment in selective breeding and sustainable feed production (Kaminski et al., 2025).

Strategic Priorities

Securing a sustainable future for the sector hinges on five strategic priorities:

1. **Strengthen transboundary governance and enforcement** through fully financed joint MCS operations and effective implementation of the LVFO Regional Plan of Action to Combat IUU Fishing (LVFO, 2022).
2. **Invest in cold chain and value addition** to capture significant economic value currently lost to spoilage and underutilised by-products (Aura et al., 2022; GIZ, 2024).
3. **Expand scientific research and monitoring**, with basin-wide stock assessments and dedicated programs for heavy metal surveillance (Oyege et al., 2025).
4. **Regulate the aquaculture boom**, enforcing spatial planning, EIAs, and environmental monitoring to control nutrient loading and disease risks (LVFO, 2021; Okechi et al., 2022).
5. **Improve access to finance, insurance, and inputs**, including support for hatcheries and feed mills, to overcome chronic supply constraints (Kaminski et al., 2025; Mwanja et al., 2022).

Overall, Lake Victoria's fisheries and aquaculture sector can still achieve ecological recovery and economic transformation, but only through coordinated regional governance, responsible aquaculture development, and a decisive pivot toward value creation within a sustainable Blue Economy framework.

6.3.5 Antimicrobial Resistance in the Lake Victoria Basin

Antimicrobial resistance (AMR) is becoming a major transboundary environmental and public-health risk in the Lake Victoria Basin, driven by rapid population growth, industrialisation, and intensified aquatic food systems (KfW Entwicklungsbank, 2025). Lake Victoria is increasingly acting as an environmental reservoir of resistant microorganisms, sustained by continuous inputs of sub-lethal antibiotics and heavy metals that accelerate microbial adaptation and co-selection (Frontiers in Microbiology, 2012; Cui et al., 2024; Abia &

Essack, 2023). Resistance is enabled through multiple mechanisms—enzymatic degradation, efflux pumps, target-site mutations and biofilm formation—and spreads efficiently via horizontal gene transfer on mobile genetic elements (Microorganisms, 2020; Samiji et al., 2024; Sheikh et al., 2023). Class 1 integrons are particularly important as markers of anthropogenic pollution and multidrug resistance (Hou et al., 2025).

Evidence from aquaculture underscores the operational and livelihood implications. Between 2020 and 2023, cage farmers reported 82+ fish mortality events, with losses exceeding 1.8 million Nile tilapia ***(Oreochromis niloticus)***, reflecting the combined effects of poor water quality, high stocking densities, temperature variability, and infections linked to drug-resistant opportunistic pathogens (Teplitz et al., 2026). Investigations have associated mortality events with taxa including *Aeromonas jandaei*, *Enterobacter hormaechei* and *Staphylococcus* epidermidis, alongside pathogens of wider aquaculture and public-health relevance such as *Acinetobacter soli*, *Bacillus cereus*, *Plesiomonas shigelloides* and *Staphylococcus* spp. Detection of *Vibrio mimicus* in nearshore waters and fish products—closely related to *V. cholerae* and often carrying mobile AMR genes—reinforces the lake's role as a persistent AMR reservoir.

AMR risk is spatially concentrated in nearshore waters influenced by urbanisation, industry and intensive cage aquaculture. Results from the 2025 Lake Victoria Joint Water Quality Survey (44 stations across nine locations) indicate elevated risk near Kisumu, Kampala–Entebbe and Mwanza (Lake Victoria Basin Commission, 2026). Winam Gulf stands out as a critical hotspot: shallow depth and limited water exchange promote contaminant accumulation, eutrophication, and resistant *Vibrio* and *E. coli* with high multiple antibiotic resistance indices (Ndegwa et al., 2025). In Uganda, the Kampala–Entebbe industrial corridor contributes untreated effluent and heavy metals that strengthen AMR through co-selection (Cui et al., 2024; Abia & Essack, 2023). Mwanza's expanding urban and port activities are also increasing resistance-gene mobility (Hou et al., 2025).

The resistance profile spans drug classes central to human medicine and aquaculture. Sulfonamide/trimethoprim resistance is linked to sul1/sul2 genes, commonly associated with class 1 integrons in polluted systems (Laht et al., 2014). β-lactam resistance is pronounced, with Winam Gulf studies reporting >70% resistance to ampicillin and cloxacillin, consistent with ESBLs such as bla_(CTX-M-15) in *E. coli* and *Salmonella* (Ndegwa et al., 2025; Samiji et al., 2024). Fluoroquinolone resistance (e.g., nalidixic acid approaching 80% in some isolates) and widespread tetracycline genes (e.g., *tetM, tetC*) further indicate persistent selective pressure from agricultural and aquaculture inputs (Samiji et al., 2024; Ndegwa et al., 2025). High multiple antibiotic resistance (MAR) indices—often above the 0.2 risk threshold—confirm the growing prevalence of multidrug-resistant bacteria.

Surveillance likely underestimates risk. Chemical methods (HPLC/mass spectrometry) may miss low-level antibiotic residues that still select for resistance; molecular thresholds can overlook low-abundance genes; metagenomics can miss rare determinants without enrichment; and culture-based methods bias toward readily grown organisms (Didelot et al., 2012; Khatiebi et al., 2023; Hou et al., 2025; Acosta et al., 2025). These constraints complicate basin-wide risk evaluation and early warning.

Addressing AMR requires a coordinated One Health response integrating environmental, animal and human health (KfW Entwicklungsbank, 2025; Lake Victoria Basin Commission, 2026). Priorities include harmonised surveillance for resistance genes and residues, stronger biosecurity and professional oversight of antimicrobial use in aquaculture, major investments in WASH in lakeshore communities, and tighter industrial pollution controls to reduce heavy-metal co-selection (Cui et al., 2024; Simiyu & Mwatelah, 2014; Abia & Essack, 2023; Teplitz et al., 2026). Without sustained regional governance and investment, resistant infections will increasingly threaten fisheries, food security and public health across a basin of over 45 million people (Lake Victoria Basin Commission, 2026).

6.4: Hydropower Generation and Regional Power Interconnection

Hydropower lies at the centre of the Lake Victoria Basin's (LVB) energy system, supplying the bulk of firm, low-cost electricity while anchoring national grids and enabling regional power trade. Yet the Basin also faces widening electricity-access gaps, rising demand, and increasing climate stress on hydropower assets, making diversification and interconnection increasingly essential. **Section 6.4** examines: the strategic role of energy in economic transformation and evolving access and generation trends (6.4.1–6.4.2); hydropower resources and their climate and environmental vulnerabilities (6.4.3); the importance of regional power interconnection for security, affordability, and utilisation of surplus capacity (6.4.4); the shift toward diversified, low-carbon systems and clean-cooking transitions (6.4.5); and rural electrification as a foundation for inclusive growth (6.4.6). It concludes with future policy and planning directions (6.4.7).

6.4.1 Overview and Strategic Importance

Energy as a Driver of Transformation

Modern, reliable, and affordable energy underpins the socio-economic transformation of the Lake Victoria Basin (LVB). National development plans consistently frame electricity as an enabler of industrialization, agro-processing, digital services, and delivery of essential public services such as health, education, and water supply. Development partners reinforce this position, emphasising that unlocking economic potential requires energy to shift from a constraint to an engine of green, inclusive growth (AfDB, 2024b). The relationship is circular: rising incomes drive electricity demand, while reliable electricity enhances productivity, competitiveness, and service delivery—especially in rural and peri-urban areas where economic activities remain constrained by limited power availability.

Regional Energy Landscape

The LVB's energy landscape combines substantial hydropower and renewable potential with persistent energy poverty. National electricity access rates range from ~12% in Burundi to >75% in Kenya and Rwanda (detailed in Section 6.4.2), while the total electricity generation by LVB Partner States has tripled since 2000, reaching 33,124 GWh in 2023. Despite this growth, electricity demand is rising faster than supply, with the Eastern Africa Power Pool (EAPP) projecting regional peak demand of 58 GW by 2030 (EAPP, 2020). Driven by the economic imperative to monetize generation surpluses—specifically Uganda's post-Karuma capacity—and enhance regional energy security, the LVB is transitioning toward an integrated power market through the expansion of cross-border transmission infrastructure and the harmonization of trading protocols under the EAPP.

Policy and Institutional Architecture

National policies promote expanded generation, diversification, and private-sector investment to ensure affordable tariffs, a strategy supported by two key regional institutions. The Eastern Africa Power Pool (EAPP) coordinates interconnection planning and electricity trade to balance regional supply and demand, while the Nile Basin Initiative (NBI), through NELSAP, anchors transboundary water-energy planning by facilitating cooperative resource management and the preparation of major hydropower and transmission projects (NBI, 2021; World Bank, 2021).

Section Structure

This section examines the Basin's hydropower resources and regional power integration through five complementary lenses: hydropower generation capacity and climate sensitivity (Section 6.4.2), electricity access patterns and progress (Section 6.4.3), regional power interconnection and trade (Section 6.4.4), energy diversification and the clean cooking transition (Section 6.4.5), rural electrification strategies (Section 6.4.6), and future policy directions (Section 6.4.7).

6.4.2 Electricity Access and Generation Trends

National Access Rates and Progress

Although the Eastern and Southern Africa region has an average electricity access rate of about 50%, national performance varies widely across the Lake Victoria Basin (Figure 6-17). Rwanda's rapid expansion—from 6% in 2009 to 75% in 2024—demonstrates the impact of coordinated public investments and off-grid innovation (World Bank, 2024c). Kenya's access rate, now above 75%, reflects sustained grid rollout and large-scale renewable deployment (IEA, 2024e). Uganda's 51% access rate (MEMD Uganda, 2023) signals steady but moderate progress, while Burundi remains severely underserved at ~12% (World Bank, 2023a), constraining economic diversification. Tanzania illustrates the difference between proximity to the grid and actual connections—only 52.7% of households are connected due to internal wiring costs and connection fees (World Bank, 2025d).

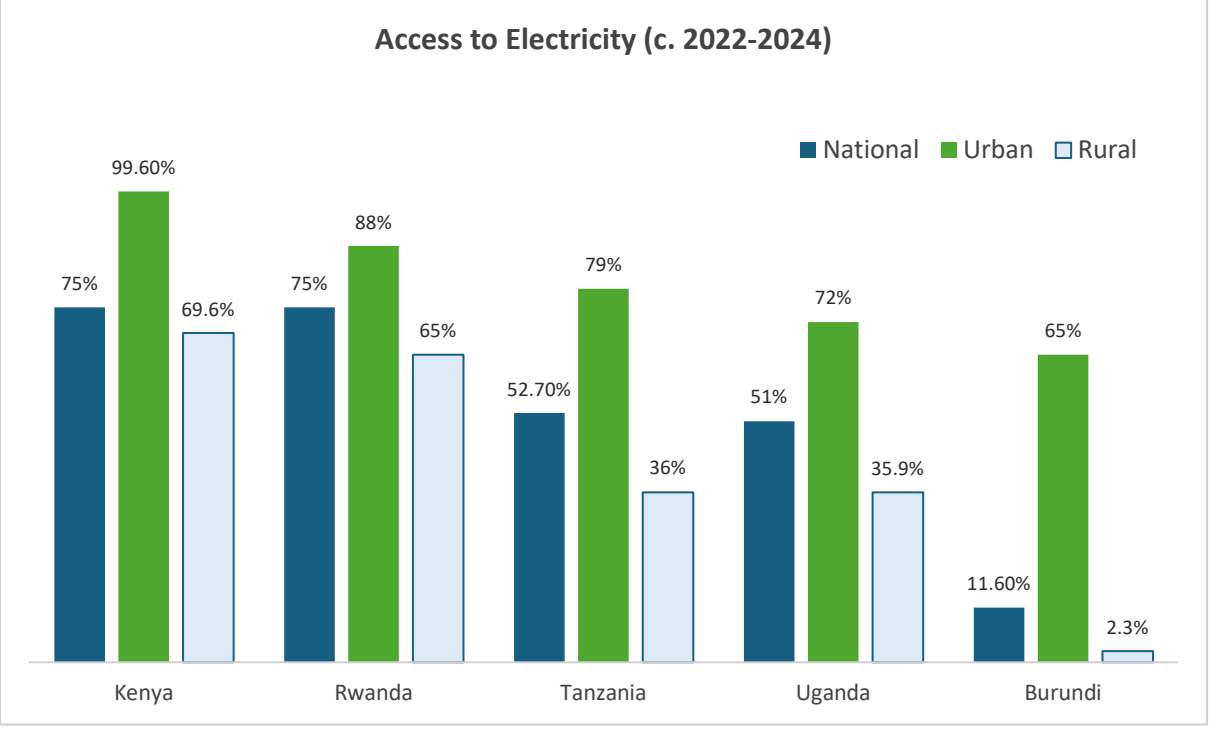


Figure 6-17. *Access to electricity in urban and rural areas in the LVB Partner States. (Sources: World Bank (2023a; 2024c; 2025c; 2025d), MEMD Uganda (2023), IEA (2024e), NISR (2025).)*

Long-Term Trends in Electricity Access (2000–2024)

These above national snapshots gain deeper meaning when viewed across the two-decade trajectory of electrification in the Basin (Figure 6-18). A clear "hockey-stick" growth pattern characterises long-term electrification trends. Progress was slow from 2000–2010, when population growth outpaced new connections, but accelerated sharply after 2012 with the rise of affordable solar technologies and large-scale programmes such as Power Africa (World Bank, 2024c; Macrotrends, 2024). This shift enabled more rapid and diversified electrification across all Partner States.

Despite this acceleration, urban–rural disparities remain the most persistent structural challenge (Figure 6-16). Urban access is now near universal in Kenya and Rwanda and improving steadily in Tanzania (World Bank, 2025d; NISR, 2025). Burundi, however, continues to face both low urban coverage and an exceptionally wide rural deficit (World Bank, 2023a). Kenya's narrowing rural gap illustrates the impact of last-mile subsidies and coordinated grid rollout (IEA, 2024e), while many rural communities in other countries remain costly to serve through grid extension alone.

The recent momentum is supported by Mission 300, a World Bank and AfDB initiative launched in 2024 to connect 300 million Africans by 2030 (World Bank, 2024c). The initiative seeks to address capital constraints in countries like Burundi and to reduce the "near-grid but unconnected" gap evident in Tanzania (World Bank, 2025d). Its programmatic approach marks a departure from short-term project financing, enabling utilities to plan long-term and scale both grid and off-grid solutions.

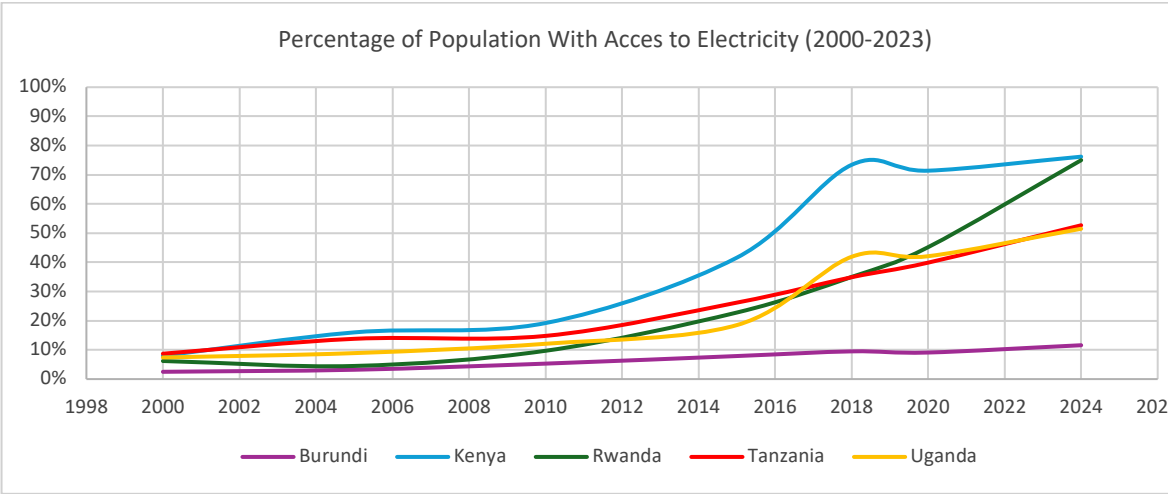


Figure 6-18. *Trends in national access to electricity in the LVB Partner States. (Sources: World Bank, 2024; Macrotrends, 2024; The GlobalEconomy, 2024; REG, 2024; UBOS, 2024).*

Overall, the Basin's electrification story shows initial divergence followed by partial convergence. Kenya surged ahead under a state-led model, while Uganda and others advanced more slowly (MEMD Uganda, 2023). After 2015, falling solar prices and integrated grid/off-grid planning enabled Rwanda and Uganda to accelerate access and narrow the gap (NISR, 2025; MEMD Uganda, 2023). As the region approaches 2030, the focus is shifting from simple connection counts to quality, reliability, and productive use, ensuring access contributes to industrialisation, irrigation, and service delivery. For Burundi, progress begins from a low base, but regional models—public-private partnerships, results-based financing, and off-grid integration—offer viable pathways to scale.

Generation Growth and Energy Mix

Over the past quarter-century, total electricity generation across the LVB Partner States more than tripled, surging from 10,362 GWh in 2000 to 33,124 GWh in 20223 (Figure 6-19). Hydropower has anchored this expansion, reinforcing its position as the region's dominant energy source. The broader energy mix has also evolved: generation from natural gas has increased since the early 2000s, while reliance on oil-fired power has steadily declined. Furthermore, diversification efforts have led to a significant increase in other renewable sources, particularly geothermal and wind energy.

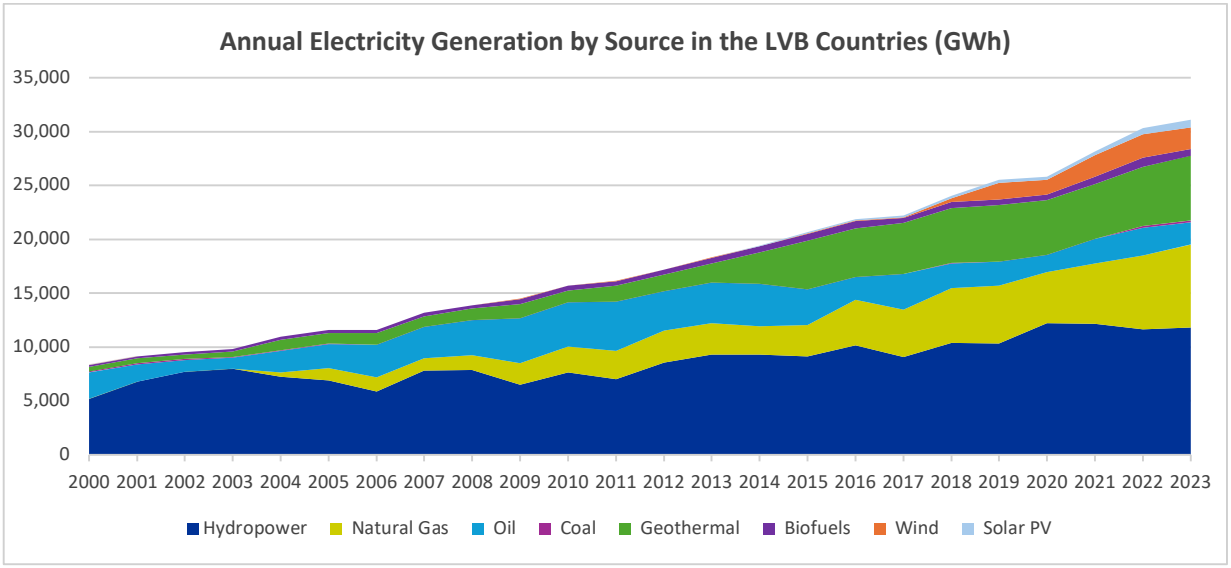


Figure 6-19. *Combined electricity generation by source by the LVB Partner. (Sources: IRENA, 2025; IEA, 2025a, 2025b, 2025c, 2025d).*

Despite the tripling of electricity production over the last quarter century, electricity demand is rising faster than supply. Kenya's consumption increased from 6.6 TWh to 10.5 TWh over a decade (IEA, 2024d). Closing this gap requires accelerated investment in both generation and transmission, particularly flexible and climate-resilient systems.

Hydropower Dominance

Hydropower constitutes the backbone of national power systems and remains the most significant renewable resource in the Basin. Kenya generates 90% of its electricity from renewables, with hydropower and geothermal forming the core (IEA, 2024e). Uganda relies heavily on the Nalubaale-Kiira complex, which contributes nearly one-third of national installed capacity (European Commission, 2024). Tanzania's 60% renewable share is similarly anchored in large hydro schemes (World Bank, 2025d). Figure 6-20 illustrates the dominance of hydropower in the region's energy mix.

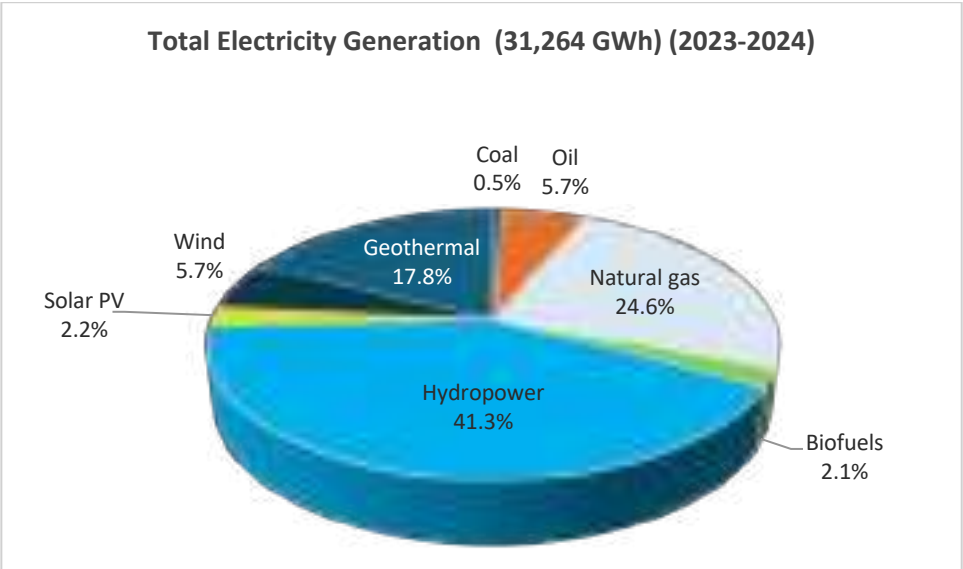


Figure 6-20. *Percent share of energy sources in the total electricity generation by the LVB Partner States in 2023-2024. (Sources: IRENA, 2025; IEA, 2025a, 2025b, 2025c, 2025d).*

This concentration creates a regional risk profile, as droughts, prolonged dry spells, and increasingly variable rainfall directly affect Lake Victoria outflows and run-of-river hydropower facilities (see Section 6.4.3 for detailed discussion of climate vulnerabilities).

6.4.3 Hydropower Resources and Climate Sensitivity

Hydropower Potential and Development Status

The Lake Victoria Basin (LVB) and wider Nile Equatorial Lakes (NEL) region possess some of Africa's most significant hydropower resources. The technically feasible potential for the NEL region exceeds 46,000 MW (ESMAP, 2010), while the Eastern Africa Power Pool (EAPP) estimates 170 GW of hydropower potential for Eastern Africa—concentrated mainly in the Democratic Republic of Congo (100 GW) and Ethiopia (45 GW) (EAPP, 2023).

Despite this exceptional endowment, only a fraction has been developed. The Nile Basin Initiative (NBI) projects approximately 26,000 MW of hydropower under current develop*ment pathways—far below the basin's total potential* (NBI, 2021). High capital costs, complex safeguard requirements, and the need for joint decision-making on shared rivers have slowed the buildout of new assets.

Yet hydropower remains the single most important renewable resource for the Basin's long-term energy security, providing low-cost baseload supply, frequency stability, and system inertia that intermittent renewables cannot yet fully match.

Major Existing Hydropower Facilities

*T*he region's electricity systems rely on a handful of large, strategically located plants along the Victoria Nile and its tributaries, supported by newer run-of-river schemes designed to minimise social and environmental impacts. These assets (Table 6-13; Figure 6-21) collectively underpin baseload generation in the Basin and will remain foundational even as solar and geothermal capacity expand.

Table 6-13. Major Hydropower Facilities in and immediately Downstream of the Lake Victoria Basin.

Facility / Complex	Country(ies)	River	Capacity (MW)	Location and Status
Nalubaale–Kiira	Uganda	Victoria Nile	380 MW	Oldest and most critical complex; regulates Lake Victoria outflows; anchors Uganda's baseload supply (NBI, 2007a; European Commission, 2024).
Bujagali	Uganda	Victoria Nile	250 MW	Downstream of Nalubaale/Kiira. European Investment Bank (2023)
Isimba	Uganda	Victoria Nile	183 MW	Downstream plant commissioned in 2019, improving grid stability and reducing reliance on thermal power (IEA, 2021).
Karuma	Uganda	Victoria Nile	600 MW	Major new cascade plant (2024), creating significant surplus capacity for regional power trade (ALN, 2025).
Muvumbe	Uganda	Muvumbe	6.5 MW	Station is in Kigarama village, Maziba Sub-county, Kabale District.
Sondu-Miriu	Kenya	Sondu Miriu	60 MW	Run-of-river scheme with 6.2 km diversion tunnel; minimal flooding footprint (KenGen, n.d.).
Sang'oro	Kenya	Sondu	20.2 MW	Located approximately 5 kilometres west of the power house of Sondu Miriu Hydroelectric Power Station; commissioned in 2013.
Rusumo Falls	Rwanda–Tanzania–Burundi	Kagera	80 MW	Run-of-river, transboundary plant jointly owned by three countries; generates ~500 GWh/year, supplies equal shares to each grid, and is strategically important for expanding access—meeting up to half of Burundi's peak demand. The plant is highly exposed to sediment loading and water hyacinth inflows originating upstream (Nile Basin Initiative, n.d.; African Development Bank, 2013).
Ntaruka	Rwanda	Nyabarongo	11.5 MW	Located in Northern Province of Rwanda, in Burera District; Rehabilitated and recommissioned in 1995, 1996 and 1997.
Rukarara	Rwanda	Nyabarongo	9.5 MW	Located in Nyamagabe District; Commissioned in 2011.
Mushishi-to-Rukarara	Rwanda	Nyanarongo	5.5 MW	Commissioned in June 2022
Mukungwa 1-2	Rwanda	Nyabarongo	12 MW	Located in Musanze District, Northern Province, Rwanda.Commissioned in 1982.
Nyabarongo 1	Rwanda	Nyabarongo	28 MW	Located in Muhanga District. Commissioned in 2015.
Nyabarongo 2	Rwanda	Nyabarongo	43.5 MW	Located on the Nyabarongo River, in Rulindo District, about 25 km from Kigali. Construction began in May 2022, expected completion in January 2025. Will irrigate 20,000 ha of farmland

Facility / Complex	Country(ies)	River	Capacity (MW)	Location and Status
Kikagati	Tanzania, Uganda	Kagera	15.6	Jointly commissioned by Presidents of Tanzania and Uganda on May 25, 2023.
Jiji-Mulembwe	Burundi	Jiji & Mulembwe Rivers	49.5	Jiji Plant (32.5 MW) inaugurated June 2025; Mulembwe component nearing completion. (European Investment Bank, 2025)
Nsongyezi	Uganda	Kagera	39	Located downstream of Kikagati. Development rights transferred from TrønderEnergi to Maji Power Limited (Berkeley Energy). Listed with a potential completion of ~ 2025 (Uganda Ministry of Works and Transport, 2025).

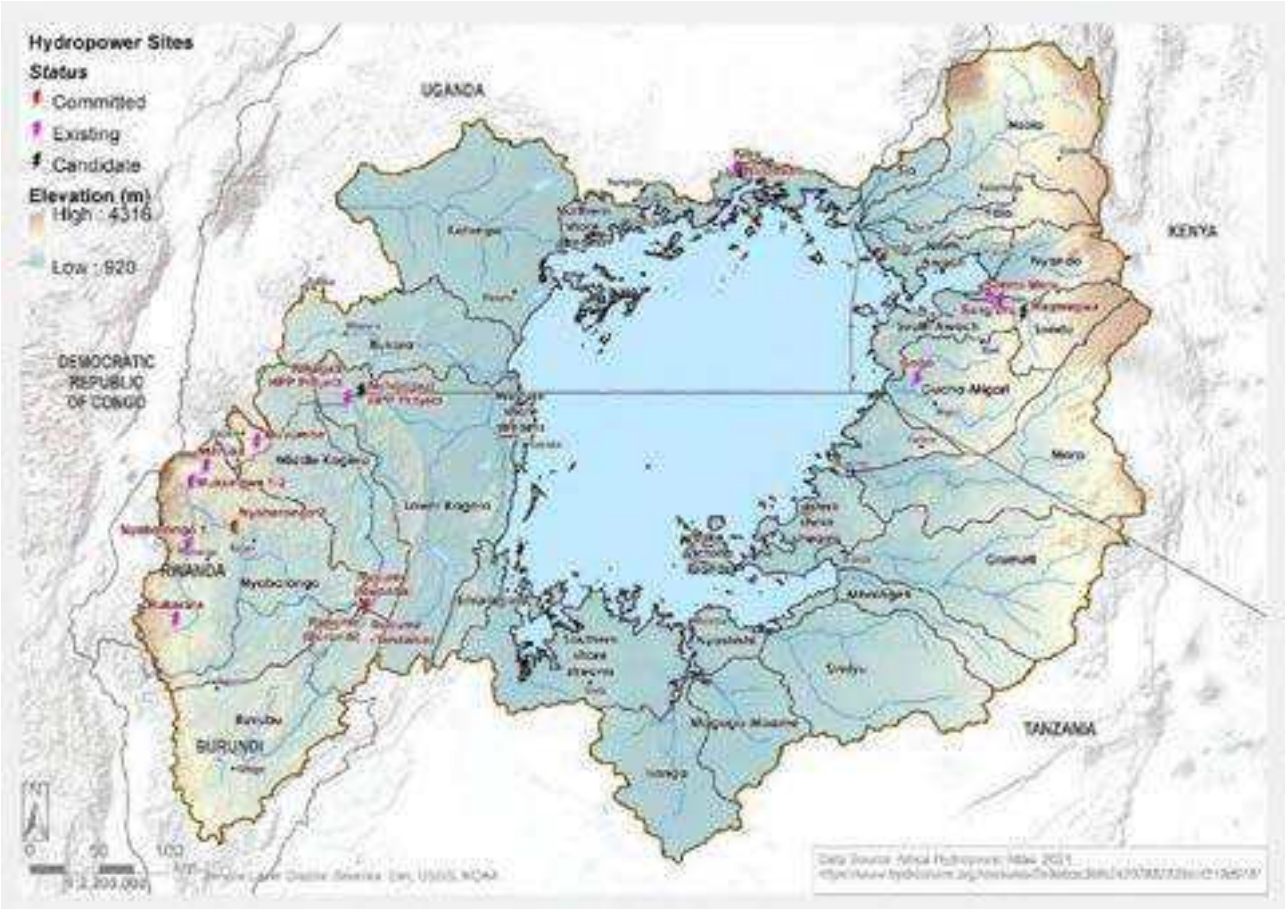


Figure 6-21. *Hydropower sites in LVB*



Figure 6-22. *Official inauguration of the 32.5 MW Jiji Power Plant in Burundi on June 24, 2025. (Source: GoB)*

Pipeline Projects and Evolving Investment Models

A new wave of hydropower development is emerging in the Lake Victoria Basin, with investment models increasingly blending public finance, concessional support, and private capital, exemplified by the Kakono Hydropower Project (87 MW) on the Kagera River led by TANESCO with multilateral funding, the Rusizi III scheme (230 MW) jointly developed by Rwanda, Burundi, and the Democratic Republic of Congo on the Ruzizi River, and the Rusumo Falls project, a US$470 million tri-national venture demonstrating the viability of large transboundary hydropower through pooled donor financing, shared safeguards, and joint ownership among Burundi, Rwanda, and Tanzania.

Recognizing fiscal constraints, AfDB's PPP Framework seeks to expand private investment in generation (AfDB, 2022), while the SEFA modernization programme is restoring aging hydropower assets. The 2023 SEFA-supported modernization pipeline—expected to add 570 MW in effective capacity—signals a shift toward maximising existing assets rather than relying exclusively on new large dams (AfDB, 2023; 2024c).

Water Demand, Design Choices, and Environmental Pressures

Hydropower in the basin has unique water-resource implications. While turbine flows are largely non-consumptive, large reservoirs create evaporative losses and alter natural flow regimes. The Nalubaale–Kiira complex, at the lake's single outlet, is particularly sensitive to Lake Victoria's water levels and plays a critical role in regulating downstream hydrology (NBI, 2007a; European Commission, 2024).

To reduce environmental and social footprints, recent investments—including Rusumo Falls and Sondu-Miriu—have favoured run-of-river designs, which avoid large impoundments but provide limited storage and flexibility.

Climate and Environmental Vulnerabilities

Hydropower reliability across the Lake Victoria Basin is increasingly undermined by environmental degradation and a rapidly changing climate. Three factors are especially consequential for both existing and new hydropower assets:

- Invasive species and sedimentation: Water hyacinth has repeatedly clogged intakes at Jinja, forcing emergency shutdowns and costly clearance operations. Sedimentation from degraded upstream catchments reduces reservoir storage and abrades turbines, shortening operational lifespans (Geosciences, 2023). The Rusumo Falls plant faces similar pressures: high sediment loads damage Kaplan turbines and reduce headpond capacity, while seasonal inflows deliver 10–15 tonnes of water hyacinth per day, frequently blocking intake screens and inflating maintenance costs (Geosciences, 2023).
- Hydrological and climate variability: Lake-level fluctuations and prolonged droughts have already reduced production at Nalubaale–Kiira, prompting costly reliance on thermal generation (NBI, 2007a; World Bank, 2014). The IPCC and IEA identify East Africa's dependence on hydropower as a structural vulnerability, noting that most dams were designed without accounting for intensifying rainfall extremes, drought cycles, and flood hazards (IPCC, 2022; IEA, 2021). The near-collapse of Malawi's hydropower system during Cyclone Idai—from 320 MW to 50 MW—illustrates the scale of potential system-wide disruption under future climate conditions (IEA, 2021).
- A reinforcing environmental–energy feedback loop: Heavy reliance on biomass for cooking drives deforestation, soil erosion, and higher sediment loads in rivers feeding the Basin (Geosciences, 2023). Increased rainfall intensity washes more nutrients into Lake Victoria, fuelling hyacinth proliferation (Lakescientist.com, 2023). Together, hyacinth and sediment reduce hydropower efficiency and force utilities to rely on diesel generation and emergency imports—diverting scarce resources away from clean-cooking transition and renewable diversification. Rusumo Falls illustrates this dynamic clearly: watershed degradation in Burundi and Rwanda elevates sediment and nutrient loads, undermines plant performance, shortens asset lifespans, and raises operational costs—reinforcing the urgency of integrated catchment management and clean-cooking solutions (see Section 6.4.5).

As such, hydropower sustainability in the LVB is inseparable from improved watershed management and accelerated adoption of clean cooking technologies.

6.4.4 Regional Power Interconnection and Trade

Rationale for Regional Power Interconnection

No single Lake Victoria Basin (LVB) country can secure affordable, reliable, and low-carbon electricity on its own. Hydrological variability, uneven resource distribution, and growing demand make regional power interconnection a structural necessity rather than a policy preference. Four factors underpin this rationale:

1. **Enhancing Energy Security:** Interconnected grids improve stability by allowing countries to pool reserves and support one another during drought-induced hydropower reductions, plant outages, or transmission failures. This shared resilience is increasingly important as climate variability intensifies.

2. Lowering Generation Costs: A regional market enables dispatch of least-cost power across borders. Countries with surplus low-cost hydropower—such as Uganda and Ethiopia—can displace expensive diesel-fired backup in neighbouring systems, improving tariff affordability and reducing public expenditure on emergency power imports (ESMAP, 2010; EAPP, 2023).
3. Commercial Utilisation of Surplus Capacity: Uganda's generation capacity reached 2,048 MW after Karuma's commissioning, against peak demand of just 987.8 MW, leaving 1,060.2 MW idle (ALN, 2025). Without export routes, this surplus represents a financial liability in the form of unused capacity charges and under-recovered investment costs. Interconnection provides the demand needed to monetise this surplus and stabilise the utility's revenue base.
4. Accelerating the Clean Energy Transition: Cross-border exchanges of hydro, geothermal, and solar power help countries meet their NDCs by reducing reliance on thermal generation and expanding access to non-fossil resources that may not be evenly distributed within national boundaries (NBI, 2017). Regional trade therefore acts as both a mitigation instrument and an adaptation strategy.

Interconnection Infrastructure

A coherent network of regional transmission lines is taking shape across the LVB, forming a "ring around the lake" and linking the Eastern Africa Power Pool (EAPP) to the Southern African Power Pool (SAPP). Progress has been significant, reflecting long-standing regional planning efforts (see Table 6-14 for a detailed status of key corridors).

- **Operational Corridors:** The Kenya–Uganda 132 kV interconnector is already active, supporting routine bilateral trade (EAPP, 2024). The 220 kV Shango–Mbarara line between Rwanda and Uganda—commissioned in 2023—now reliably transfers an average of 27.1 MW, demonstrating the commercial viability of regional exchange (NBI, 2024).
- **Ongoing and Planned Expansion:** Priority projects include the 400 kV Kenya–Uganda upgrade (due 2025), the Uganda–Tanzania Interconnection Project (UTIP) linking EAPP to SAPP by 2028, and associated transmission lines from the Rusumo Falls hydropower plant to Burundi, Rwanda, and Tanzania (World Bank, 2021, 2024g). These projects collectively strengthen redundancy, expand transfer capacity, and open new trade routes to larger regional markets.

The economic logic of this build-out is clear: Uganda's large surplus can only be absorbed through export markets, and Kenya—by far the region's largest industrial load—offers the primary outlet. While the Uganda–Rwanda line provides proof of concept, the 400 kV Kenya–Uganda corridor is pivotal for achieving true market liquidity and ensuring financial sustainability of upstream generation investments (EAPP, 2024).

> "During dry seasons, many valley tanks, pans, shallow wells, and streams recede or dry out. Simultaneously, pasture biomass decreases, forcing herders—especially pastoralists in Kenya, Tanzania, and Uganda's cattle corridor—to move longer distances in search of water ....."

Table 6-14. *Status of Key LVB Regional Power Interconnection Projects (c. 2024)*

Project Corridor	Voltage (kV)	Length (km)	Status	Estimated Completion
Uganda – Rwanda	220	172	Operational (trade began Oct 2023) (NBI, 2024)	Completed
Kenya – Uganda	132	N/A	Operational (EAPP, 2024)	Completed
Kenya – Uganda (Upgrade)	400	N/A	Under Construction (EAPP, 2024)	2025
Uganda – Tanzania (UTIP)	400	N/A	Feasibility Completed (EAPP, 2024; World Bank, 2024g)	2028
Tanzania – Zambia	400	N/A	Under Construction (EAPP, 2024)	2028
DRC – Rwanda	220	N/A	Under Construction (EAPP, 2024)	2025

Institutional Framework

The emerging regional grid is supported by an increasingly mature institutional architecture.

- Eastern Africa Power Pool (EAPP): EAPP coordinates market design, develops the regional grid code, harmonises transmission tariffs, and sets the rules for cross-border trade. A key milestone was the 2023 ratification of the Independent Regulatory Board (IRB) Secretariat—hosted in Kampala—which will oversee compliance, tariff approval, and dispute resolution across member countries (African Development Bank, 2024d; ERA, 2025).
- NELSAP: Serves as the principal facilitator of cross-border power projects, leading feasibility studies, environmental assessments, and Power Purchase Agreement (PPA) negotiations. Its coordination role was instrumental in delivering the Uganda–Rwanda interconnection (NBI, 2024).

These institutional developments converge toward the expected launch of the EAPP regional market in 2025 (ERA, 2025), marking the shift from ad hoc bilateral exchanges to structured, rules-based regional trading.

6.4.5 Energy Diversification and Clean Cooking Transition

Biomass Dependence and Its Impacts

Household energy use in the Lake Victoria Basin (LVB) remains overwhelmingly biomass-based, with the percentage of households reliant on firewood or charcoal for cooking ranging from 69% in Kenya to 98% in Burundi (Figure 6-23). The total energy supply in the LVB Partner States shows heavy dominance by biofuels and waste particularly in Burundi, Rwanda and Uganda (Figure 6-23). This dependency is a major driver of deforestation, catchment degradation, and higher sediment loads, which in turn accelerate turbine wear, reduce reservoir storage, and undermine hydropower reliability (as discussed in Section 6.4.3). Indoor air pollution from inefficient stoves and poorly ventilated homes contributes to widespread respiratory illness, disproportionately affecting women and children.

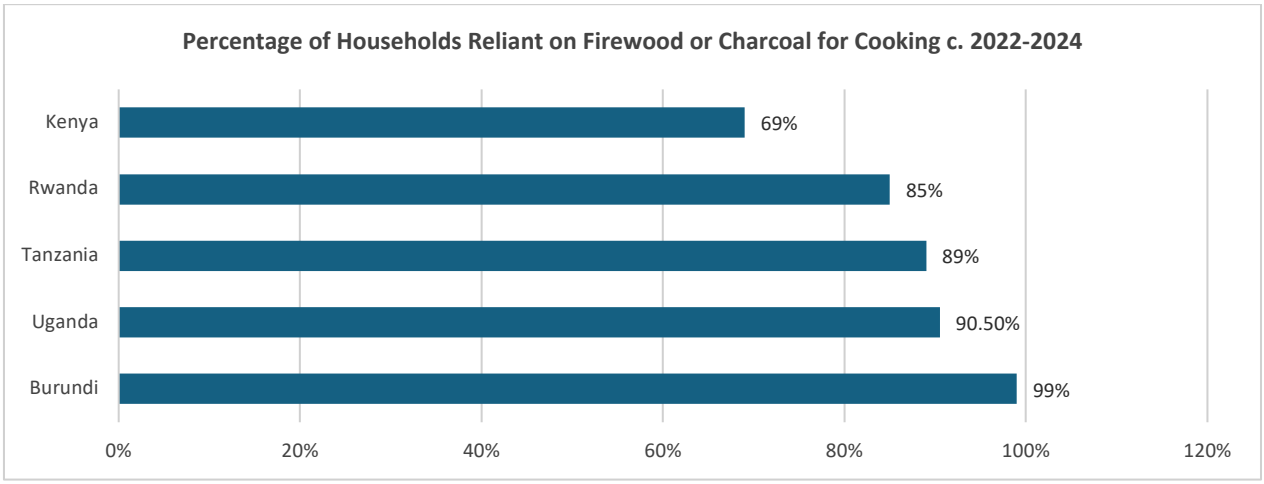


Figure 6-23. *Percentage of households in the LVB countries that use firewood or charcoal for cooking. (Sources: World Bank, 2025c; 2025d;, MEMD Uganda, 2023;, IEA, 2024; NISR, 2025.*

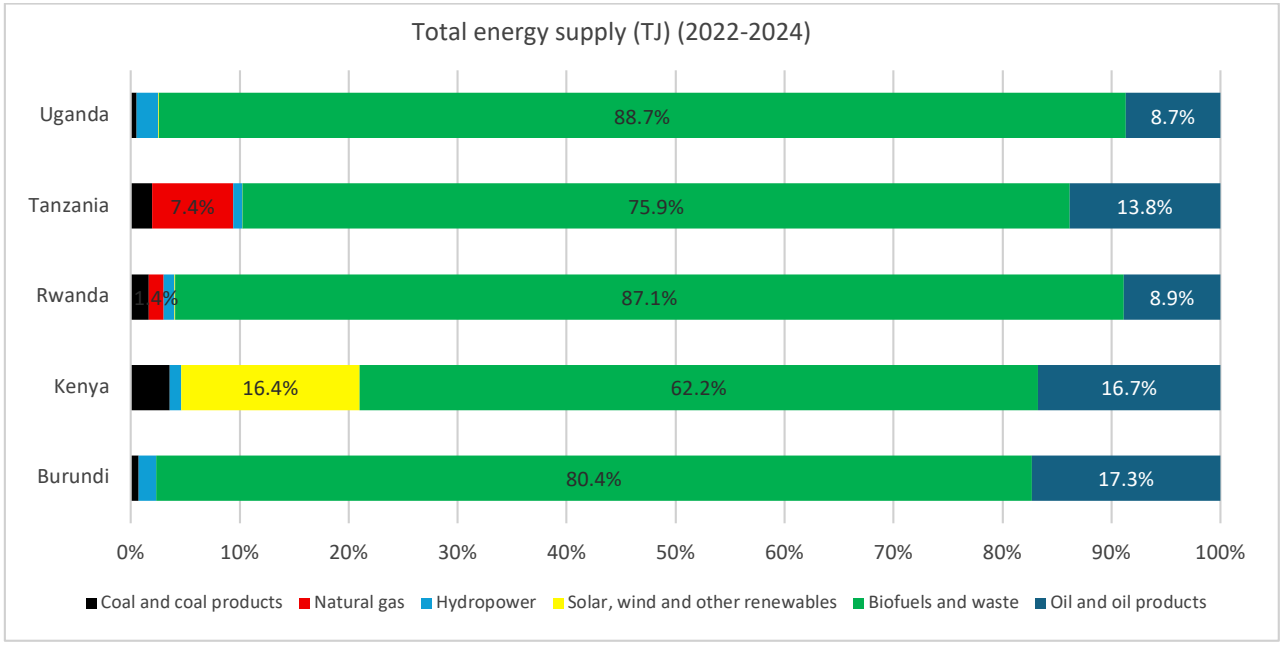


Figure 6-24. *Percentage of energy sources in the total energy supply of the LVB countries I 2022-2024. Total energy supply was Burundi (69,793 TJ); Kenya (1,268,854 TJ); Rwanda (216,942 TJ); Tanzania (1,117,201 TJ); Uganda (1,014,851 TJ). (Sources: World Bank, 2025c; 2025d;, MEMD Uganda, 2023;, IEA, 2024; NISR, 2025.*

Recognising the negative effects of overdependency on biofuels, the LVB countries have adopted ambitious clean-cooking transition targets. Tanzania's goal of 75% clean-cooking access by 2030 (World Bank, 2025d), Uganda's target of 50% by 2040 (Ministry of Energy and Mineral Development, 2023), and Kenya's plan for universal access by 2028 (IEA, 2024e) reflect a shift toward modern fuels and efficient technologies. Achieving these targets would substantially reduce biomass demand, ease watershed pressure, and improve public health outcomes.

Recent national survey data underscore how persistent biomass use remains despite electrification gains: in Rwanda, 92.5% of rural households rely on firewood for cooking, and only 5% use modern gas or electric stoves (NISR, 2025). Burundi's rural electrification rate of just 2.3% (World Bank, 2023) entrenches nearly universal biomass dependence and reinforces the link between traditional cooking fuels, watershed degradation, and hydropower vulnerability.

Diversifying the Electricity Mix

Reducing vulnerability to hydrological variability requires broadening the region's electricity mix. The LVB has strong, underutilised renewable potential:

- **Geothermal:** Kenya continues to anchor regional diversification, with geothermal providing 47% of national electricity generation (IEA, 2024d) (Figure 6-24) and an estimated 10,000 MW resource potential (ICLEI, 2024)—making it one of the world's largest untapped geothermal provinces. Its performance is stable across seasons and drought years, offering crucial load-following capacity.
- **Solar and Wind:** Tanzania's National Renewable Energy Strategy sets clear 2030 targets—463 MW solar, 500 MW wind, 130 MW geothermal (Ministry of Energy, 2024a)—intended to stabilise supply and reduce dependence on imported fuels. Kenya's grid already benefits from 16% wind (including Africa's largest wind farm at Lake Turkana) and 4% grid-connected solar, complementing hydropower during dry spells (IEA, 2024e).
- **Methane and Bioenergy:** Rwanda's Lake Kivu methane extraction provides a climate-resilient baseload option, with 26 MW installed and additional projects under development (Rwanda Energy Group, n.d.-c). Agricultural residues, such as bagasse from sugar mills, also offer distributed bioenergy solutions that can displace diesel generation.



Figure 6-25. *Wellhead plants of British Green Energy Geothermal (GEG) at Olkaria, Kenya (source: GEG/ Lydur Skulason)*

The Role of Solar Mini-Grids and Off-Grid Systems

Decentralised electrification has become a structural component of energy planning in the region. Mini-grids and standalone solar systems now form a permanent pillar of national access strategies—especially where terrain or settlement patterns make grid extension prohibitively expensive.

Rwanda aims for a 52% on-grid / 48% off-grid split in its universal electrification pathway, relying heavily on mini-grids in remote highland areas (SEforALL, 2024).

Kenya's 75% electricity-access rate (2024) is supported by 9.2% from standalone solar and almost 1% from mini-grids, reflecting the region's largest PAYG solar market (World Bank, 2025c). The rise of PAYG Solar Home Systems has been especially transformative, enabling low-income households to access modern lighting and appliances without upfront capital barriers (IEA, 2024b).

Distributed solar systems reduce grid pressure, improve resilience during climate-induced hydropower deficits, and provide rapid, modular expansion options for underserved communities.

National household surveys confirm this structural shift: Rwanda's 2024 EICV7 shows that 22% of households use standalone solar systems, and rural access stands at 65% (NISR, 2025). Uganda's rural access (35.9%) and Burundi's extremely low 2.3% (World Bank, 2023) demonstrate that mini-grids and SHS are indispensable for rural electrification across the Basin.

Barriers to Renewable Scale-Up

Despite strong potential, several constraints slow diversification:

- **Financing barriers:** High risk premiums limit access to the US$25 billion annually required to achieve universal access in Africa (IEA, 2024h).
- **Grid limitations**: Ageing infrastructure and 23% technical and commercial losses in Kenya (IEA, 2024d) restrict the integration of variable renewables.
- **Regulatory delays hinder** private investment in utility-scale and decentralised systems.
- **Affordability constraints limit adoption** of modern cooking devices, batteries, and efficient appliances.

Quality-of-service constraints worsen these barriers: Burundi's National Energy Compact reports that more than 50% of connected households experience frequent outages (PACTE National pour l'Énergie, 2024), undermining reliability, productive use, and diversification progress.

Addressing these financial, technical, and regulatory constraints is essential for building a resilient, low-carbon energy system and reducing hydropower stress across the Basin.

6.4.6 Rural Electrification

Strategic Importance

Rural electrification is a foundational driver of socio-economic transformation in the Lake Victoria Basin (LVB). Reliable electricity enables enterprise development, mechanised agriculture, cold-chain expansion, digital connectivity, and improved delivery of health and education services. It is also the most durable pathway for reducing household biomass dependence—cutting deforestation, soil erosion, and sediment inflows that undermine hydropower infrastructure (World Bank, 2025c). In this way, electrification directly reinforces watershed protection and the long-term performance of the region's hydropower assets (see Section 6.4.3).

Institutional and Policy Framework

Governments have strengthened national electrification policies, such as Uganda's Energy Policy 2023, which integrates grid and off-grid development, and Tanzania's Rural Energy Master Plan, which prioritises cost-effective last-mile distribution. Development partners now play an outsized role: the World Bank and AfDB's Mission 300 and the ASCENT programme together represent the largest coordinated push for electricity access in the region's history, combining concessional finance, risk-mitigation instruments, and targeted subsidies to reach

100 million people in Eastern and Southern Africa (World Bank, 2024b). New public–private models—such as Burundi's Weza Power and private PAYG operators in Kenya—signal a diversification of delivery approaches that can accelerate connections in underserved rural markets (OECD, 2024; World Bank, 2025c).

Access and Progress: A Three-Track Approach

The LVB's electrification strategy now operates along three complementary tracks designed to match technologies with settlement patterns, demand characteristics, and cost structures.

- **Grid Extension:** Grid densification and low-cost technologies (single-wire earth-return, optimized transformers) are reducing per-connection costs in areas already near the network. Kenya's "Last Mile" and Uganda's support for low-voltage extension highlight this approach, which remains the most cost-effective solution for peri-urban and high-density rural zones (Ministry of Energy and Mineral Development [Uganda], 2023; World Bank, 2025c).
- **Mini-Grids:** For remote but clustered populations, mini-grids provide higher capacity and better service quality than standalone systems. Uganda's 2023 Energy Policy outlines tariff-setting, licensing, and grid-arrival rules that de-risk investment, while private operators increasingly deploy solar-hybrid mini-grids where anchor loads exist—such as agro-processing centres or fishing communities.
- **Standalone Off-Grid Systems (SHS):** PAYG solar and modular SHS have expanded rapidly where grid extension is uneconomical. Rwanda's target of 48% off-grid access and Kenya's 9.2% standalone PV penetration demonstrate their central role in achieving universal access (Sustainable Energy for All, 2024; World Bank, 2025c). These systems support lighting, phone charging, refrigeration, and small appliances—enabling micro-enterprises and improving resilience for households farthest from the grid.

Challenges and Opportunities

While electricity generation has expanded—Uganda alone maintains a surplus of approximately 1,060 MW (ALN, 2025)—distribution and affordability remain the principal barriers to universal access. Extending networks into sparsely populated rural areas requires high upfront investment, and many households struggle to afford connection fees, internal wiring, or productive-use appliances. Limited demand density can also undermine the financial viability of rural mini-grids.

Opportunities lie in business models that ease liquidity constraints and stimulate demand: PAYG solar, targeted connection subsidies, community-managed mini-grids, and financing schemes for appliances such as irrigation pumps, refrigerators, and milling equipment (Ministry of Energy and Mineral Development [Uganda], 2023). These interventions help ensure that new connections translate into income generation, making electrification both socially beneficial and commercially sustainable.

6.4.7 Potential Future Directions

Integrated Water–Energy–Climate Planning

Long-term energy security in the LVB will depend on replacing siloed planning with integrated water–energy–climate approaches. Hydropower design, operations, and rehabilitation must explicitly incorporate climate-scenario modelling, as recommended by the IEA and World Bank, to address rising variability in flows and sediment loads (IEA, 2021; World Bank, 2014). This also requires coupling generation planning with demand-side efficiency.

Digitalization and System Modernization

A more distributed energy system—mixing grid, mini-grid, and household-level technologies—requires modern digital infrastructure for monitoring, planning, and customer management. Rwanda's goal of completing a national SCADA/DMS platform by 2027 exemplifies the region's direction, enabling predictive maintenance, real-time grid balancing,

and reduced outage durations. Kenya's high technical and commercial losses highlight the urgency of digital metering, automated billing, and fault-detection systems (IEA, 2024d). At the same time, digital payment platforms remain fundamental to PAYG solar, productive-use appliance financing, and emerging e-cooking markets.

Diversifying the Energy Mix

To reduce hydrological risk, the region must accelerate investment in low-carbon, non-hydro resources. Kenya's geothermal fields—already among the world's top performers—offer reliable baseload power and significant expansion potential (IEA, 2024e; ICLEI, 2024). Solar and wind resources across the Basin provide high-quality, rapidly deployable options that complement hydropower seasonality (World Bank, 2025d). Rwanda's methane gas resources on Lake Kivu add an additional indigenous, flexible-generation option and can support system stability during periods of hydropower stress.

Strengthening Regional Power Trade through the EAPP

The upcoming operationalization of the EAPP regional market in 2025 represents a structural shift toward coordinated regional power balancing (ERA, 2025). A strong, independent regulatory institution is needed to harmonize grid codes, ensure transparent tariff methodologies, and manage dispute resolution (African Development Bank, 2024d). Effective implementation would allow countries to draw on regional surplus capacity during droughts, reduce reserve-margin requirements, and optimize investment planning—moving from fragmented bilateral PPAs to a dynamic, least-cost regional market (ESMAP, 2010).

Advancing Gender-Responsive Energy Planning

Addressing gender disparities remains central to equitable electrification. Women disproportionately shoulder the health impacts of biomass use and the time burden of fuel collection, making energy access a critical enabler of education, income generation, and safety (World Bank, 2023c). Uganda's and Kenya's emerging policy reforms show how gender considerations can be embedded in access planning, but implementation gaps persist. Deeper gender mainstreaming—including financing for women-led energy enterprises, tailored credit products, and capacity-building—aligns with AfDB's call for women to be recognized as active actors in the renewable energy value chain rather than passive beneficiaries.

> "To reduce hydrological risk, the region must accelerate investment in low-carbon, non-hydro resources. Kenya's geothermal fields—already among the world's top performers—offer reliable baseload power and significant expansion potential"

6.5: Navigation

Inland water transport (IWT) on Lake Victoria is re-emerging as a strategic pillar of the East African Community's (EAC) agenda for regional integration, trade competitiveness, and low-carbon mobility. Once the backbone of cross-lake commerce, the lake's rail–water network is now being revived through port rehabilitation, new vessels, and digital safety systems, even as safety gaps, regulatory weaknesses, and uneven infrastructure remain. **Section 6.5** examines the strategic role of IWT in supporting Basin economies and the AfCFTA (6.5.1), trends and constraints in navigation on Lake Victoria, including ports, fleets, and safety systems (6.5.2), and the longer-term prospects for extending navigation along the Kagera River (6.5.3). It then assesses intermodal connectivity with road and rail corridors and the wider implications for regional value chains and tourism (6.5.4), before concluding with priority actions to secure a safe, climate-efficient, and economically competitive navigation system (6.5.5).

6.5.1 Strategic Importance of Inland Water Transport

Inland Water Transport (IWT) on Lake Victoria is increasingly recognised as a core enabler of the East African Community's (EAC) ambitions for regional integration, trade competitiveness, and climate-resilient mobility. As the world's second-largest freshwater lake, its extensive navigable waters provide an underutilised but highly strategic natural transport corridor capable of shifting large volumes of freight more efficiently than existing road systems (Lake Victoria Basin Commission [LVBC], 2021b).

Historical Role and Current Revival

Historically, Lake Victoria functioned as a major transport backbone, with a well-coordinated rail–water intermodal network enabling seamless movement of cargo and passengers across Kisumu, Port Bell, Jinja, and Mwanza. These ports, equipped with roll-on/roll-off (Ro-Ro) terminals, facilitated efficient transfers between maritime and rail systems and supported vibrant regional commerce (Lund University, 2023a; World Bank, 2008).

The decline of this system—driven by decades of underinvestment, vessel deterioration, and limited port rehabilitation—shifted freight to road corridors that are now heavily congested and environmentally costly. The current EAC strategy seeks to reverse this decline through major port upgrades (e.g., Kisumu, Mwanza South, and Port Bell), new vessel investments, and a revival of the multimodal rail–lake system as part of a broader logistics reform agenda (FAST-Infra, 2024). This is not a new vision, but a restoration of a proven, cost-effective transport model.

Economic and Political Significance

Lake Victoria underpins the economy of more than 40 million people living in the Basin. Although the specific GDP share of IWT is not isolated in national accounts, the lake-dependent fisheries economy—fully reliant on affordable vessel access and transport—contributes approximately 4% of Basin GDP and supports over 5 million livelihoods (LVBC, 2021b).

IWT provides the only reliable transport lifeline for numerous islands and remote shoreline communities, ensuring access to markets, health services, and regional supply chains (World Bank, 2019a). Economically, IWT reduces transport costs for bulk commodities, strengthens the competitiveness of small traders, and supports the movement of agricultural products across borders.

Politically, the lake is recognised as an anchor of EAC cooperation and has been designated as both a Regional Economic Growth Zone and an Area of Common Economic Interest. These designations highlight its pivotal role in unifying the region's two major transport arteries—the **Northern Corridor**, which connects through Kisumu and Port Bell, and the **Central Corridor**, which links through Mwanza. Together, these routes form a single, integrated logistics system that connects the seaports of Mombasa and Dar es Salaam to the inland economies of Uganda, Rwanda, Burundi, and eastern DRC (LVBC, 2021b).

Relevance to the AfCFTA

The implementation of the African Continental Free Trade Area (AfCFTA) substantially increases demand for efficient, high-capacity logistics. With road networks already overstretched, the region cannot scale trade volumes without shifting significant freight to inland waterways. AfCFTA-aligned analysis suggests that unlocking Lake Victoria's full transport potential will require a modern fleet of around 100 vessels—indicating a clear pipeline for vessel acquisition, port expansion, and navigational safety investments (FAST-Infra, 2024). Strengthening IWT is thus essential for enabling regional value chains, lowering transport costs, and positioning the EAC to benefit from continental-wide market integration.

Environmental and Energy-Efficiency Benefits

IWT is demonstrably one of the most energy-efficient modes for transporting bulk cargo, offering major cost and emissions advantages relative to road and rail systems (FAST-Infra, 2024). Its superior fuel economy translates directly into a smaller carbon footprint, making it central to the EAC's transition towards lower-emission transport.

A single fuel barge from the Kisumu oil jetty can replace more than 50 trucks on the roads—reducing congestion, cutting diesel use, and minimising road wear. Similar benefits apply to the transport of clinker, fertiliser, fuel, and agricultural commodities. These savings improve freight competitiveness while also reducing the heavy maintenance burden on regional highways.

Because of its low-carbon profile, modernised IWT is increasingly attractive to climate finance institutions, with the African Development Bank identifying navigation infrastructure as a priority area for green and resilient mobility investments.

6.5.2 Navigation on Lake Victoria

Navigation on Lake Victoria is undergoing a major transformation, driven by renewed investment in ports, vessels, and digital safety systems. The lake's transport network consists of long-distance international routes—led by the Mwanza–Port Bell axis, historically handling up to 85% of marine trade—as well as extensive local routes that link remote islands and shoreline communities to national markets (World Bank, 2008; Uganda Freight Forwarders Association, 2019).

After decades of decline, freight volumes are beginning to recover. Port Bell's traffic, which fell from nearly 500,000 tonnes in the late 1990s to 30,000 tonnes in 2015 (World Bank, 2018), is slowly improving, with the reactivated Mwanza–Port Bell service moving about 66,000 tonnes in 2018/19 (Uganda Freight Forwarders Association, 2019). This recovery, however, contrasts sharply with the region's long-term ambitions: Uganda's new Bukasa Port is designed for 5.2 million tonnes annually—an eighty-fold increase over current performance—highlighting a strategy centred on large-scale, infrastructure-led expansion rather than incremental demand growth (International Hydrographic Organization, 2024a).

Port and Landing Site Infrastructure

Port infrastructure remains uneven across the Basin **(Table 6-15)**. Kenya and Tanzania have modernised Kisumu and Mwanza, while Uganda's Port Bell and Jinja remain dilapidated, lacking dredging, lighting, and basic cargo equipment (Onyango, 2022). This imbalance undermines regional efficiency and has prompted strong calls to accelerate Uganda's stalled Bukasa Port development.

Table 6-15. *Inventory and Status of Primary Lake Victoria Ports*

Port	Country	Status	Key Facilities & Capacities	Recent / Planned Upgrades
Kisumu	Kenya	Operational / Rehabilitated	Rail Ferry Link (MGR), Ro-Ro, Oil Jetty (70M liter capacity), Container handling	Rehabilitation completed. Kisumu Shipyards established. Resilient infrastructure program ongoing. (International Hydrographic Organization, 2024a)
Mwanza (South & North)	Tanzania	Operational / Upgrading	Rail Ferry Link (MGR), Ro-Ro, Floating Dock, Ferry terminals	New floating dock (USD 16M) constructed at Mwanza South. World Bank supporting upgrades at both ports. (World Bank, 2019a; International Hydrographic Organization, 2024a)
Port Bell	Uganda	Operational / Dilapidated	Rail Ferry Link (MGR), Ro-Ro, Dry Dock (2,000-tonne capacity)	In poor state. Lacks cargo-handling equipment, insufficient lighting, obstructed by shipwreck. Needs dredging. (Onyango, 2022)
Jinja	Uganda	Operational / Dilapidated	Rail Ferry Link (MGR), Ro-Ro	In poor state, with limited freight handling. (Onyango, 2022)
Bukasa	Uganda	Under Construction (Stalled)	Conventional Berths, Container Terminals (ICD), Ro-Ro	Greenfield port. Planned capacity of 5.2 million tonnes/year. Project has faced significant delays. (International Hydrographic Organization, 2024a; Onyango, 2022)
Bukoba	Tanzania	Operational	Ferry Terminal	World Bank supporting planned rehabilitation. (World Bank, 2019a)
Musoma	Tanzania	Operational	Ferry Terminal	World Bank supporting planned rehabilitation. (World Bank, 2019a)
Kemondo Bay	Tanzania	Operational	Ferry Terminal	World Bank supporting planned rehabilitation. (World Bank, 2019a)

Support Infrastructure

A new support ecosystem is emerging to service upgraded fleets and improve operational reliability. Shipbuilding and repair capacity has strengthened through the Kisumu Shipyards, a new floating dock at Mwanza, and private shipyard investments in Uganda. Human-capacity development has expanded through new maritime training centres in Entebbe and Kisumu. Crucially, the Multinational Lake Victoria Maritime Communications and Transport (MLVMCT Project)—financed by the African Development Bank—extends GSM coverage across the lake, establishes a regional maritime communication network and 12 Search and Rescue centres, and provides the digital backbone needed to attract commercial operators while improving logistics and stimulating trade, tourism, and private investment (Lake Victoria Basin Commission, 2023). Navigation safety has also improved with the installation of 86 new Aids to Navigation under LVEMPII.

Beyond safety and communications, regional investments are increasingly addressing climate resilience of support infrastructure. The Climate Resilience and Sustainable Transformation of the Lake Victoria Basin Initiative (CRESTI LVB), funded by the Global Environment Facility, complements maritime upgrades by climate-proofing landing-site infrastructure against intensifying storms, lake-level variability, and flooding risks. By promoting integrated land, water, and forest management, CRESTI LVB reduces sedimentation and shoreline

degradation around ports and landing sites, enhances biodiversity, and strengthens the long-term reliability of transport and fisheries infrastructure. Together, these investments shift the lake's support systems from basic safety provision toward a more resilient, environmentally integrated foundation for sustained commercial navigation and livelihoods.

The Lake Victoria Fleet

The Lake Victoria fleet (**Table 6-16**) consists of a dominant informal sector of small wooden boats—over 25,000 in Tanzania and about 15,000 in Uganda (International Hydrographic Organization, 2024a)—and a growing formal fleet of large vessels, comprising both rehabilitated legacy ferries and modern specialised ships.

Table 6-16. *Analysis of Lake Victoria Vessel Fleet (New and Rehabilitated) (Sources: International Hydrographic Organization, 2024a; FAST-Infra, 2024; Uganda Freight Forwarders Association, 2019.*

Vessel Name	Country	Type	Capacity	Status
MV New Mwanza	Tanzania	Ro-Pax	4 decks, 1,200 passengers, 400t cargo, 20 small vehicles, 3 trucks	New-build (largest freshwater vessel in Africa)
MV Victoria	Tanzania	Ro-Pax	1,200 passengers, 200t cargo	Rehabilitated
MV Butiama	Tanzania	Ro-Pax	200 passengers, 100t cargo	Rehabilitated
MV Umoja	Tanzania	Train Ferry	19 wagons (1,200t)	Rehabilitated
MV Uhuru II	Kenya	Train Ferry	1,800t (22 wagons)	New-build
MV Uhuru	Kenya	Train Ferry	1,180t (22 wagons)	Rehabilitated
MV Mpungu	Uganda	Ro-Ro Freight	1,000t cargo (21 trailers)	New-build (Private Sector)
MT Elgon	Uganda	Tanker	Total capacity (with MT Kabaka) approx. 10M liters	New-build (Private Sector)
MT Kabaka	Uganda	Tanker	Total capacity (with MT Elgon) approx. 10M liters	New-build (Private Sector)
MV Kaawa	Uganda	Train Ferry	1,248t	Operational (Legacy)



Figure 6-26. *The MV New Mwanza commissioned in January 2026. This is the largest freshwater vessel in Africa (Source: thevoiceofafrica.com)*

These investments reflect three different but complementary national strategies: Kenya's focus on rail-compatible train ferries; Uganda's emphasis on private-sector Ro-Ro and fuel tankers; and Tanzania's mixed-use Ro-Pax model.

Maritime Safety and Accident Prevention

Lake Victoria remains one of the world's deadliest inland waterways, with estimated annual drowning fatalities ranging from 1,500 to 5,000, concentrated among fishermen and small-boat users (Roberts et al., 2022). Poor weather, overloading, substandard vessel conditions, low lifejacket use, and untrained operators remain the leading causes (Pando et al., 2018; Tugume, 2024). The HIGHWAY project demonstrated that reliable weather alerts can reduce fatalities by up to 30% (Roberts et al., 2022), providing a strong proof-of-concept for the MLVMCT system. As summarised in **Table 6-17**, recent regional interventions—ranging from new Aids to Navigation to the MLVMCT safety-communications system—are beginning to address these long-standing safety gaps.

Table 6-17. *Summary of Maritime Safety and Navigation Interventions.*

Intervention	Lead Agency / Funder	Key Components	Status/ Reach
Multinational Lake Victoria Maritime Communications & Transport (MLVMCT)	LVBC / AfDB	Establishes 3 Maritime Rescue Coordination Centres (MRCCs) (Mwanza, Entebbe, Kisumu). Extends GSM communication over the lake.	Ongoing. Entebbe MRCC sub-center operational in 2025.
Aids to Navigation (AtoN) Installation	LVBC / LVEMPII	Design, supply, and installation of buoys, lighthouses, and hazard markers.	Completed. 86 AtoN installed (46 TZ, 22 UG, 18 KE).
Regional Emergency Number	EAC Council of Ministers	Gazettement of 110 as the toll-free emergency mobile number for SAR on the lake.	Implemented. Roll-out planned for all Partner States.
HIGHWAY Project	(International Collaboration)	Provided new, enhanced marine weather forecasts and warnings for mariners.	Completed.
National SAR Capacity	National Govts (e.g., KMA, UPDF)	SAR boats, patrol vessels, operational personnel (Marine Police, Coast Guard).	Ongoing. Kenya received 5 new SAR boats (2024). (Uganda's SAR is functionally operated by UPDF/Marine Police.

Sources: *LVBC (n.d.-a; 2023); African Development Bank Group (2015; n.d.-a); International Hydrographic Organization (2024b); Roberts et al. (2022); Kenya Maritime Authority (n.d.); and International Organization for Migration (2025).*

Maritime Security

Security risks are mainly economic—gear theft, cage-fish theft, IUU fishing, smuggling, and human movement—rather than military (East African Community, 2022). State marine forces address organised crime and border issues, while local Beach Management Units remain central to reducing livelihood-related theft and conflict.

Policy, Legal, and Institutional Framework

Governance is fragmented. The regional EAC Lake Victoria Transport Act (2007) provides the overarching framework, but national laws vary significantly. The most serious gap occurs in Uganda, where the modern Inland Water Transport Act (2021) explicitly excludes Lake Victoria, reverting regulation to the 2007 EAC Act, whose ocean-based standards are unsuited for the 15,000+ small wooden boats operating on the lake. This "regulatory dualism" undermines safety efforts and is widely viewed as the most urgent policy issue requiring harmonisation (Safe Transport and Survivors Support Uganda, 2025).

Recent Interventions and Ongoing Challenges

Recent interventions include port reconstruction in Kisumu and Mwanza **(Textbox 6-2)**, fleet modernisation across all Partner States, and implementation of the MLVMCT safety and communications system. Nonetheless, persistent challenges remain: Uganda's deteriorated port infrastructure continues to constrain regional connectivity; safety standards are poorly enforced in the informal fleet; and intermodal inefficiencies threaten the competitiveness of the entire corridor. Environmental management gaps—including pollution control and dredging impacts—also require attention. Notably, regional documentation remains largely silent on social inclusion issues, particularly the limited participation of women and the accessibility needs of vulnerable groups, representing a major blind spot in sector planning.

Textbox 6-2: Lake Victoria Navigation Improvement Project

The Lake Victoria Basin Commission (LVBC) is implementing a portfolio of Navigation Improvement Projects valued at approximately USD 25 million to modernize and secure lake transport across the Lake Victoria corridor. The investments focus on the rehabilitation and upgrading of key port and landing facilities, strategic dredging of critical navigation channels, and the installation of essential safety and navigational infrastructure.

Port infrastructure upgrades include the improvement of berths, jetties, cargo-handling areas, passenger terminals, and intermodal linkages to road and rail networks, aimed at reducing congestion, enhancing operational efficiency, and supporting growing volumes of regional trade. Targeted dredging works are being undertaken to remove sediment build-up in shallow approaches and shipping lanes, improving year-round navigability and reducing vessel grounding risks, especially during low-water periods.

To address persistent lake safety challenges, the project also includes the installation of modern maritime safety systems, including navigation aids (buoys, beacons, and markers), vessel tracking and communication systems, search-and-rescue equipment, and strengthened regulatory enforcement capacity. Collectively, these interventions are designed to reduce accidents and loss of life, lower transport costs, improve the reliability of cross-border lake transport, and strengthen the role of Lake Victoria as a safe, efficient, and climate-resilient regional transport corridor supporting trade, tourism, fisheries, and economic integration

6.5.3 Navigation on the Kagera River

The Kagera River, the largest river flowing into Lake Victoria, is not presently a viable navigation corridor but is increasingly viewed as a long-term strategic opportunity to extend inland water transport into the landlocked economies of Rwanda and Burundi. Regional institutions—including the EAC, UNECA, and AU-PIDA—have repeatedly highlighted its potential to provide a cheaper and more efficient transport alternative for bulk freight and passengers, strengthening regional trade links and reducing reliance on congested road networks.

Navigability and Constraints

Existing studies identify major limitations that explain the river's current non-navigable status. The Kagera's natural hydrology presents significant challenges: multiple stretches of rapids and cataracts interrupt continuous passage, and wide seasonal variations in discharge create fluctuating water depths unsuitable for commercial navigation (Nile Basin Initiative, 2009). These natural constraints are compounded by man-made barriers—most notably low-clearance bridges such as Kyaka Bridge, which physically obstruct vessel movement along key sections.

Ecological factors further complicate river access near its confluence with Lake Victoria. At Kasensero, the river mouth is frequently clogged by water hyacinth, requiring periodic clearance to maintain even basic access for small craft (Nile Basin Initiative, 2009). Taken together, these factors mean that Kagera navigation remains at the pre-feasibility level, with no evidence of past or present commercial riverine transport.

Future Prospects and Regional Strategy

Despite these constraints, the Kagera continues to feature prominently in long-term regional transport planning. In 2024, UNECA launched a new feasibility study on trade facilitation through Lake Victoria and Kagera/Akagera River navigation (UNGM, 2024). The terms of reference reveal a broader systems approach: the river's viability is explicitly tied to the ongoing modernisation of Lake Victoria's transport ecosystem—particularly upgrades to Kisumu Port, expansion of its oil jetty, and improvement of lake-based freight services.

The emerging vision positions the Kagera as a feeder corridor that would connect Rwanda and Burundi to Lake Victoria and then to the Northern Corridor logistics chain. Under this model, freight would move by river to the lake, transfer at Kisumu for rail transport via the MGR/SGR network, and continue to the Port of Mombasa (World Bank, 2019b). This integrated, multi-modal routing is intended to provide landlocked states with a lower-cost alternative to long road hauls. However, its feasibility ultimately depends on a fully functional and reliable Lake Victoria IWT system; without that upstream backbone, Kagera River navigation is unlikely to be technically viable or commercially attractive.

6.5.4 Intermodal Connectivity and Economic Integration

The effectiveness of the Lake Victoria IWT modernisation programme depends not on the lake alone but on its performance within a wider regional transport system. The strategic ambition is to transform the lake from a basic point-to-point service into a high-capacity "liquid highway" linking road and rail networks across Kenya, Tanzania, and Uganda (Lake Victoria Basin Commission, 2021b). Central to this shift is the introduction of modern roll-on/roll-off (Ro-Ro) vessels—such as Uganda's MV Mpungu—which allow trucks and trailers to embark directly, reducing cargo handling and turnaround times and enabling more efficient road-water-road routing (FAST-Infra, 2024).

Rail–Water Connectivity: The Critical Interface

Historically, Kisumu, Mwanza, Port Bell, and Jinja were designed as rail-wagon Ro-Ro terminals integrated with the Metre Gauge Railway (MGR) (Lund University, 2023a). This interface is now being revived: Kenya has rehabilitated the MGR to Kisumu and reintroduced MGR-compatible train ferries (MV Uhuru I and II), enabling direct linkage with Mwanza's railhead (International Hydrographic Organization, 2024a). The Figure 6-27 shows the MV Uhuru docked in Kisumu.



Figure 6-27. *The MV Uhuru I (Kenya) carrying rail fuel tankers (Source: standardmedia.co.ke)*

However, the emergence of the Standard Gauge Railway (SGR) introduces significant interoperability challenges. Without careful integration, the incompatibility between SGR and MGR gauge systems could increase trans-shipment steps and costs, reducing the competitiveness of lake transport. World Bank analysis warns that poorly coordinated SGR development could depress lake freight volumes, undermining otherwise strong investments in ports and vessels (World Bank, 2018). Efficient, low-cost trans-shipment at Kisumu and Mwanza is therefore essential; if delays persist, freight is likely to remain on the simpler but more expensive road corridors.

Road and Airport Connectivity

Road networks remain essential for connecting ports to the hinterland, supported by ongoing upgrades to port access roads and the use of Ro-Ro vessels to transport trucks directly across the lake (World Bank, 2019a; FAST-Infra, 2024). While major airports—Mwanza, Entebbe, and Kisumu—are located close to port facilities, available documentation provides no evidence of meaningful intermodal integration between maritime operations and air freight.



Figure 6-28. *Tourists arrive at Entebbe International Airport. (Source: eagle.co.ug)*

Catalytic Role for SEZs and Tourism

Intermodal improvements are expected to stimulate broader economic activity, including lake-based tourism and Special Economic Zones. The MLVMCT project explicitly links safer, digitally enabled navigation with increased investor confidence in transport, tourism, and water-based industries. The development logic is sequential: improved safety and security create a predictable operating environment,

which in turn becomes the foundation for larger-scale investments in SEZs, logistics parks, and tourism ventures along the lake.

6.5.5 Recommendations and Strategic Priorities

The analysis of Lake Victoria's navigation system points to several priority actions needed to secure a viable, safe, and integrated inland water transport corridor.

1. **Intermodal connectivity** must be de-risked. The success of the rail–water–rail model depends on resolving the SGR–MGR gauge incompatibility and establishing efficient, low-cost trans-shipment hubs at Kisumu and Mwanza. An EAC-level technical task force should lead this coordination to protect the competitiveness of the entire corridor (World Bank, 2018).

2. The region must urgently address the **regulatory gap** that leaves the informal small-boat sector—over 25,000 wooden vessels—outside effective safety oversight. Harmonised, tiered regulations tailored to these vessels are needed to bridge the disconnect between the 2007 EAC Act and national laws, which is a core driver of the lake's persistent safety crisis (Roberts et al., 2022; Safe Transport and Survivors Support Uganda, 2025).

3. The **safety-technology** backbone should be fast-tracked. Evidence from the HIGHWAY project shows that improved weather forecasting can reduce fatalities by up to 30% (Roberts et al., 2022). Completing the MLVMCT system—including lake-wide GSM coverage and fully operational Maritime Rescue Coordination Centres—offers the most cost-effective pathway to reducing risk and attracting investment (Lake Victoria Basin Commission, 2023; International Hydrographic Organization, 2024b).

4. Investments should align with a "**green port, low-carbon hub**" strategy. The low-emission profile of inland water transport provides a strong basis for mobilising climate finance. Priority areas include climate-resilient infrastructure and improved port facilities for pollution management (FAST-Infra, 2024; East African Community, 2022).

5. Governments should remove **public-sector bottlenecks** that inhibit private investment. The emergence of new privately financed vessels indicates market confidence, but inefficiencies at critical Ugandan ports—particularly Port Bell and Jinja—continue to deter operators and weaken regional integration (Onyango, 2022). Targeted rehabilitation of these facilities is therefore essential.

6. **Maritime security** should follow a dual-track model. State security agencies should focus on transnational threats such as smuggling, while Beach Management Units—embedded in fishing communities—should be strengthened to address gear theft and localised resource conflicts that affect most lake users.

7. A **regional maritime data** and monitoring system is needed to fill persistent information gaps, including passenger volumes, accident data, and gender participation. Mandating and resourcing the LVBC to lead a unified data programme will improve planning, regulation, and accountability across the sector.

6.6 Tourism

Tourism in the Lake Victoria Basin (LVB) sits at the intersection of environmental stewardship, regional integration, and local livelihood transformation. The Basin combines some of Africa's best-known terrestrial parks with a largely underdeveloped lacustrine tourism potential, and is recognised by the EAC as a key Economic Growth Zone. Tourism generates major shares of GDP and export earnings in several Partner States, yet its long-term viability depends critically on reversing pollution, habitat loss, and water-quality decline in the lake and its catchments. **Section 6.6** examines the strategic role and performance of tourism in the Basin (6.6.1), the portfolio of land- and lake-based attractions (6.6.2), and the state of infrastructure and services that enable or constrain competitiveness (6.6.3). It then reviews visitor trends and market structure (6.6.4), the sector's environmental linkages and vulnerabilities (6.6.5), and the evolving policy, legal, and institutional frameworks, including community-based tourism models (6.6.6), before outlining priority actions to secure a sustainable, inclusive tourism future for the LVB (6.6.7).

6.6.1 Overview and Strategic Importance

The Lake Victoria Basin (LVB) combines globally renowned wildlife destinations with the largely untapped potential of Africa's largest lake. Recognised by the East African Community (EAC) as an *Economic Growth Zone*, the Basin is central to regional socio-economic transformation, with tourism positioned as a major driver of jobs, foreign exchange, and local enterprise development (Lake Victoria Basin Commission, 2021).

Yet the sector's strategic value is inseparable from the Basin's ecological integrity. Severe environmental degradation—pollution, habitat loss, and declining water quality—poses an existential risk to the long-term viability of tourism (Drakenberg et al., 2007). Safeguarding the Basin's ecosystems is therefore not only an environmental priority but an economic imperative.

Economic Significance and Performance

Tourism is among the largest contributors to GDP and exports in Kenya, Tanzania, and Uganda, and has shown a robust post-pandemic rebound. Region-wide, the sector contributes roughly 10% of GDP and 17% of export earnings, with 2023 receipts exceeding 2019 levels by 24%.

- **Tanzania recorded 2.14 million** visitors and USD 3.9 billion in tourism earnings in 2024, supported by strong recovery trends documented by national statistics and UNWTO (National Bureau of Statistics, Tanzania, n.d.).
- **Kenya registered 2.39 million** arrivals and USD 3.5 billion in earnings, reinforcing its position as a regional leader.
- **Uganda received 1.37 million** visitors and earned USD 1.28 billion in 2024, continuing steady post-COVID recovery (Ministry of Finance, Planning and Economic Development, Uganda, 2024).
- **Rwanda earned USD 620 million** from 1.4 million visitors, reflecting its high-value tourism model (The Great Lakes Eye, 2025).
- **Burundi, though still early in sector development**, derives 2–3.5% of GDP from tourism.

The above national trends are reflected in the Basin-wide performance metrics presented in **Table 6-18**, which summarises recent arrivals, earnings, and growth rates across all LVB Partner States.

Despite strong national performance, the specific tourism economy of the *Lake Victoria Basin* remains poorly quantified. Most economic studies focus on the declining Lake Victoria fishery—the world's largest inland fishery—supporting millions of livelihoods. With overfishing and ecosystem degradation accelerating, multiple blue-economy assessments highlight **lacustrine tourism** as a high-potential diversification pathway (Frontiers, 2022).

Table 6-18. *Direct Tourism Performance in LVB Partner States (2023–2024)*

Country	International Arrivals (2024)	Tourism Earnings (2024)	% Change from 2023	Key Sources
Burundi	~328,000 (2023 proj.)	Data unavailable	2–3.5% of GDP	Enhanced Integrated Framework (n.d.)
Kenya	2.39 million	USD 3.5 billion	+31.5%	Tourism Research Institute Kenya (2025)
Rwanda	>1.4 million (2023)	USD 620 million	—	The Great Lakes Eye (2025)
Tanzania	2.14 million	USD 3.9 billion	+15.7%	NBS Tanzania (n.d.)
Uganda	1.37 million	USD 1.28 billion	+26%	Ministry of Finance Uganda (2024)

Divergent National Strategies within a Regional Framework

Although marketed under the shared **"Visit East Africa"** brand, Partner States pursue distinct competitive strategies:

- **Kenya and Tanzania – High-Volume, Diversified Tourism:** Large traditional markets built around safari and coastal products, each targeting **5 million annual tourists** (Government of Kenya, 2025).
- **Rwanda – High-Value, Low-Volume Model:** Prioritises yield per visitor, generating **USD 620 million from 1.4 million tourists,** with a deliberate sustainability focus (The Great Lakes Eye, 2025).
- **Uganda – High-Growth, Emerging Model:** Expanding beyond wildlife to cultural, adventure, and niche tourism, supported by competitiveness and infrastructure reforms (Uganda Tourism Board, 2020).
- **Burundi – Nascent, Rebuilding Model:** Early-stage efforts emphasise policy development, security improvements, and investment attraction.

For investors, this creates a multi-layered market: a unified regional identity for broad appeal, but differentiated national models requiring tailored engagement.

Tourism and Regional Integration

Tourism development is central to the EAC's integration agenda, anchored by the Lake Victoria Basin Commission (LVBC), which coordinates sustainable development across the Basin (Lake Victoria Basin Commission, 2021; Lake Victoria Basin Commission, 2007). The EAC Tourism Marketing Strategy 2021–2025 operationalises this mandate by promoting cross-border tourism circuits that link flagship destinations across Kenya, Tanzania, and Uganda, thereby encouraging multi-country itineraries and broader regional exploration. It further strengthens mobility and market integration through the EAC Single Tourism Visa, which facilitates seamless travel between Kenya, Uganda, and Rwanda and significantly reduces administrative barriers for international visitors (Economic Policy Research Centre, 2015). Complementing these efforts, the Strategy advances the harmonisation of accommodation and tour-operation standards

across Partner States to ensure consistent service quality and improve visitor confidence (East African Community, n.d.). Together, these interventions position the Lake Victoria Basin as a cohesive, multi-experience destination with reduced travel friction and more reliable quality assurance.

The Sustainability Imperative

A critical contradiction defines the sector: while the EAC promotes the LVB as a premier tourism destination, the Basin's ecological decline undermines its competitiveness. Pollution, eutrophication, and falling water levels have been flagged as major threats. Scientific assessments consistently confirm that ecosystem health is the foundation of tourism viability, not an optional consideration (Royal Society Publishing, 2021; PubMed Central, 2022).

In essence, tourism cannot grow if the lake continues to degrade. Environmental recovery—especially improved water quality and catchment protection—is therefore a prerequisite for sustaining tourism investment and economic returns.

6.6.2 Tourism Attractions and Activities

The Lake Victoria Basin (LVB) hosts a diverse portfolio of tourism assets (**Table 6-19; Figure 6-28)**), marked by a structural imbalance: its terrestrial attractions are globally established and in some cases strained by over-use, while its extensive lake-based environments—comprising islands, wetlands, and open water—remain underdeveloped yet rich in potential for sustainable diversification.

Land-Based Attractions

The Basin's terrestrial parks form the foundation of East Africa's safari economy. Tanzania's **Serengeti National Park,** a UNESCO World Heritage Site, anchors the Northern Circuit and remains world-renowned for the Great Migration, but faces mounting concerns over visitor pressure and infrastructure demands (UNESCO World Heritage Centre, 2012). Adjacent to it, Kenya's **Masai Mara National Reserve** endures acute overcrowding, with vehicle densities far exceeding sustainable thresholds, causing habitat degradation and wildlife disturbance (WIT Press, 2010). Additional watershed parks in Rwanda and Burundi, such as Akagera, Nyungwe, and Kibira, contribute further biodiversity value.

The region also hosts a strong cultural-heritage portfolio. Kenya's **Thimlich Ohinga**, a UNESCO-listed 14th-century dry-stone settlement, remains the most prominent archaeological site. Historical towns including Kisumu, Entebbe, Jinja, Mwanza, and Bukoba continue to serve as regional tourism hubs. Community-based tourism initiatives across the Basin provide culturally grounded experiences and enhance local benefit sharing (World Bank, 2016).

> "The EAC Tourism Marketing Strategy 2021–2025 operationalises this mandate by promoting cross-border tourism circuits that link flagship destinations across Kenya, Tanzania, and Uganda, thereby encouraging multi-country itineraries and broader regional exploration."

Table 6-19. *Inventory of Key Tourism Assets in the Lake Victoria Basin*

Asset	Country	Type	Key Attractions	Management
Serengeti National Park	Tanzania	Land-Based Park	Great Migration, "Big Five" Safari	Tanzania National Parks (TANAPA)
Masai Mara Nat. Reserve	Kenya	Land-Based Park	Great Migration River Crossings	Narok & Trans Mara County Gov.
Rubondo Island Nat. Park	Tanzania	Lake-Based Island	Chimpanzee Trekking, Sitatunga, Sport Fishing	Tanzania National Parks (TANAPA)
Ssese Islands	Uganda	Lake-Based Island	Recreation (Quad Biking, Golf), Relaxation	Kalangala District / Private Sector
Mabamba Bay Wetland	Uganda	Wetland (IBA)	Shoebill Stork Sighting (Canoe Tours)	Mabamba Wetlands Eco-Tourism Assoc. (Community)
Ngamba Island Sanctuary	Uganda	Lake-Based Island	Chimpanzee Sanctuary & Feeding	CSWCT (NGO Trust)
Thimlich Ohinga	Kenya	Cultural Site	14th-Century Dry-Stone Settlement (UNESCO)	National Museums of Kenya
Saanane Island Nat. Park	Tanzania	Lake-Based Island	Wildlife Viewing (Zebras, Lizards), Hiking	Tanzania National Parks (TANAPA)
Ukerewe Island	Tanzania	Lake-Based Island	Cultural Tours, Hiking, Largest Inland Island	Mwanza Region / Private Sector

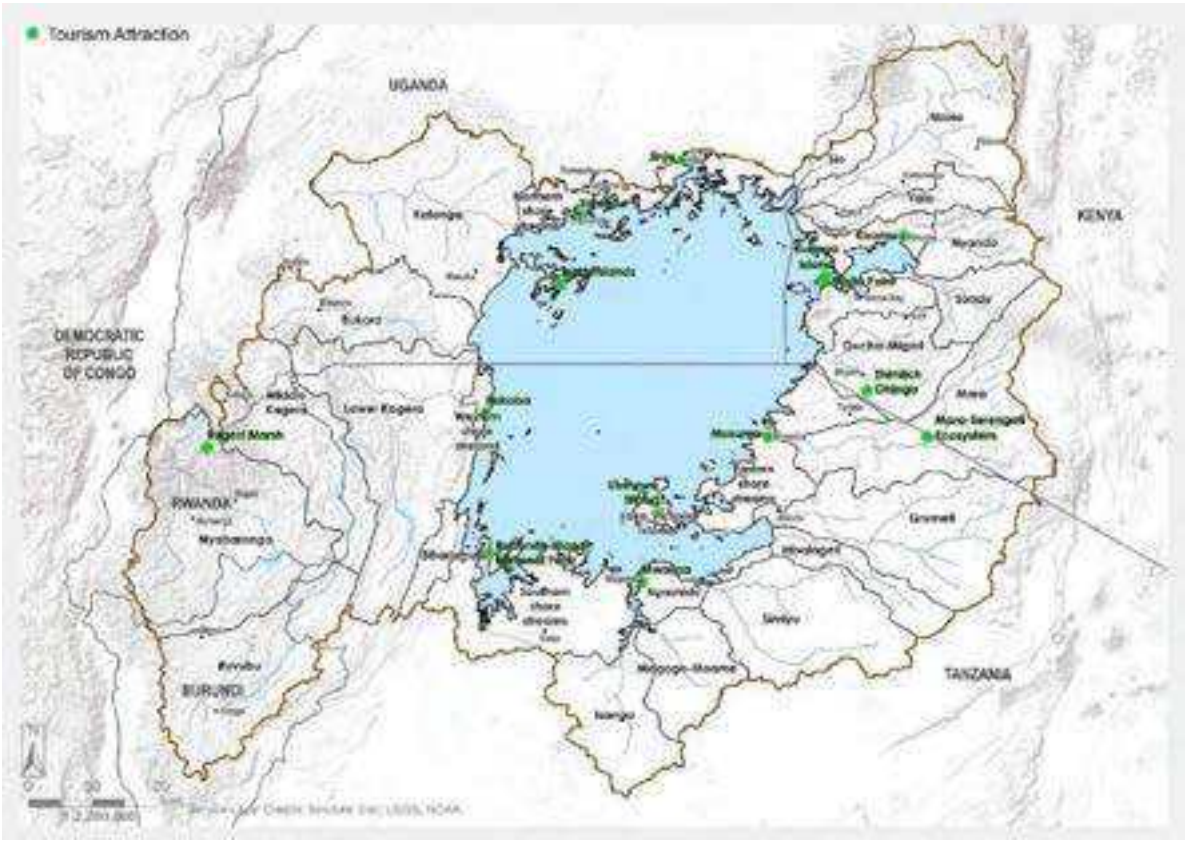


Figure 6-29. *Top tourism sites in LVB*

Lake-Based Attractions

In contrast to the mature terrestrial parks, lake-based tourism is emerging but underexploited. Rubondo Island National Park in Tanzania demonstrates a high-value, low-impact model centred on chimpanzee trekking, guided walks, and controlled sport fishing—activities aligned with strict conservation management. Uganda's Ssese Islands, particularly Bugala Island, cater to leisure and recreation through boating, angling, and nature walks, while Ukerewe Island and Saanane Island National Park in Tanzania offer cultural and light wildlife experiences. Ngamba Island Chimpanzee Sanctuary, near Entebbe, stands out as a flagship conservation attraction.

Wetland ecotourism is exemplified by Uganda's Mabamba Bay, a Ramsar site renowned for Shoebill viewing. Community-led canoe tourism in Mabamba provides a replicable model for low-impact, locally beneficial operations.

Recreational tourism—including sport fishing, sailing, birdwatching, and lake cruises—holds considerable yet largely unrealised potential across the Basin.

Strategic Implications

This portfolio reveals two complementary realities: the major terrestrial parks are reaching ecological and management limits, whereas lake- and wetland-based attractions remain underdeveloped but demonstrate strong performance where conservation-linked, low-volume models—such as Rubondo, Ngamba, and Mabamba—are applied. These cases offer a clear, evidence-based pathway for expanding the Basin's tourism economy while safeguarding ecological integrity.



Figure 6-30. *Tourisms at the Ngamba Island Chimpanzee Sanctuary on Lake Victoria, Uganda.(Source: travel.com)*

6.6.3 Tourism Infrastructure and Services

The competitiveness of tourism in the Lake Victoria Basin (LVB) depends heavily on the quality of its enabling infrastructure. A consistent pattern emerges across the region: while air connectivity and maritime safety have improved considerably, basic land-based infrastructure—especially roads and sanitation—lags behind, constraining access, visitor experience, and the overall credibility of the Basin's high-end tourism positioning.

Land-Based Infrastructure Constraints

Road access remains the single largest infrastructural bottleneck. In Kenya's portion of the Basin, fewer than 50% of roads are paved, creating major accessibility challenges for protected areas and emerging tourism circuits, particularly during rainy seasons (County Government of Kisumu, 2018). Accommodation quality is improving in established hubs, but distribution is uneven and large parts of the Basin remain underserved. More critically, inadequate water and sanitation systems undermine both public health and the tourism product: sanitation coverage in Kenya's Basin counties is described as "abysmal," with 60% lacking basic sanitation, and untreated wastewater continues to contribute directly to lake pollution (County Government of Kisumu, 2018; World Bank, 2021). These deficits erode environmental quality and diminish the visitor experience, creating a hard ceiling on the sector's capacity to compete in higher-value markets.

Air and Lake Transport Infrastructure

In contrast, air connectivity is a major regional strength. A strategic triangle of international airports—Entebbe, Kisumu, and Mwanza—provides rapid access to both terrestrial parks and lake-based destinations, enabling multi-country circuits and acting as the logistical backbone of regional tourism flows (European Investment Bank, 2010). Lake transport is improving but still constrained: ferry and port infrastructure remains outdated and has long been considered a barrier to economic and tourism development, though significant modernisation efforts are underway in Kisumu, Mwanza, and Entebbe.

The Basin has experienced historic maritime safety challenges, but the last decade has seen important reforms. The Lake Victoria Transport Act (2007) and its accompanying Safety and Fees Regulations (2010) establish a modern regulatory framework. The installation of 86 Aids to Navigation across Kenya, Uganda, and Tanzania, and the designation of "110" as the regional maritime emergency number, have substantially enhanced safety (East African Community, 2018; IHO, 2024). An AfDB-supported Maritime Rescue Coordination Centre (MRCC) network—anchored in Mwanza with sub-centres in Kisumu and Entebbe—represents a major step toward building a safe, investable lake transport system (African Development Bank, 2016).

Strategic Implications

A stark mismatch persists between the Basin's high-end tourism ambitions and the realities of inadequate road infrastructure and weak sanitation (County Government of Kisumu, 2018). Yet the region's improving air access and strengthened maritime safety regime constitute the minimum enabling conditions for unlocking private investment in lake-based tourism. By reducing transport risks and improving connectivity, EAC-led infrastructure investments are laying the foundation for developing the Basin's underutilised lacustrine tourism potential.

6.6.4 Visitor Trends and Market Analysis

Visitor trends in the Lake Victoria Basin (LVB) reveal a resilient, multi-layered tourism market, shaped by long-term growth in international arrivals and sustained by a strong domestic and intra-regional visitor base. Longitudinal data (**Figure 6-31**) show steadily rising international arrivals across Kenya, Tanzania, Rwanda, and Uganda since 2000, interrupted only by the sharp pandemic-era decline and a full recovery to pre-2020 levels by 2024. Burundi remains an outlier in the region, with international arrivals stagnating over the same period. Earnings trends (**Figure 6-32**) closely mirror arrivals, but also highlight persistent disparities in revenue performance:

although the gap in visitor numbers among Kenya, Tanzania, Rwanda, and Uganda has narrowed over time, their tourism earnings diverge significantly—reflecting the differing strategic models pursued by each country.

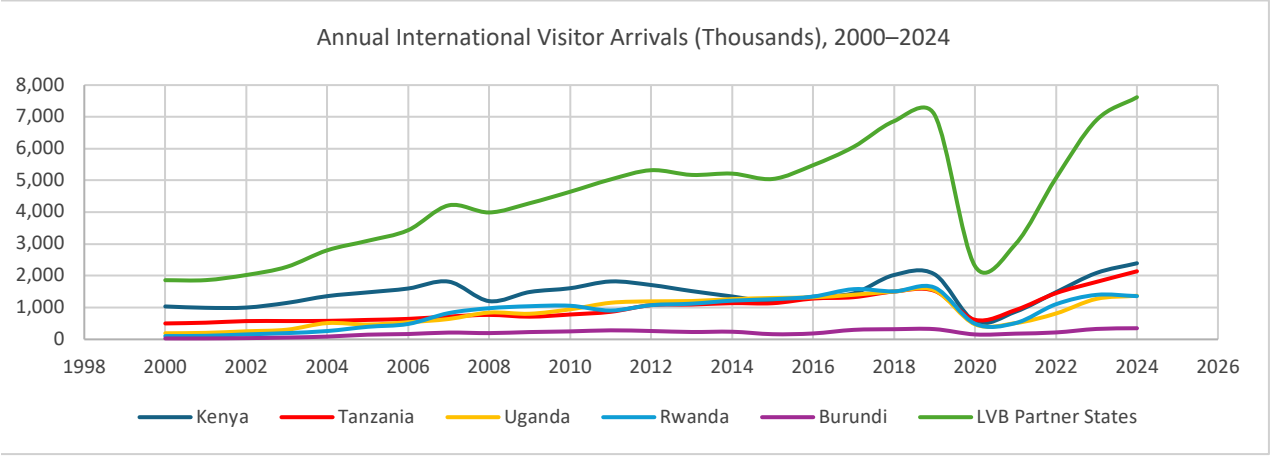


Figure 6-31. *Annual International Visitor Arrivals in the LVB Partner States (Thousands), 2000–2024. (Sources: World Bank (2000-2018); KNBS (2025); NBS (2025); MTWA (2025); RDB (2025).*

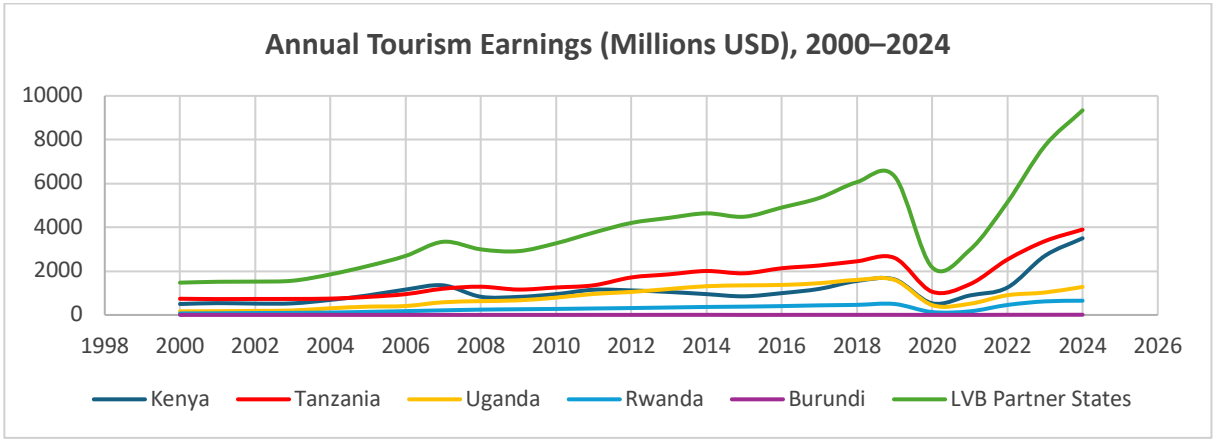


Figure 6-32. *Annual Tourism Earnings (Millions USD), 2000–2024 of the LVB Partner States (Thousands), 2000–2024. (Sources: World Bank (2000-2020); TRI (2025); BoT (2025); MTWA (2025); RDB (2025)).*

Recent statistics reinforce this trajectory. In 2024, Kenya received 2.39 million international arrivals, Tanzania 2.14 million, and Uganda 1.37 million, contributing to a regional rebound in which EAC tourism receipts were 24% higher than pre-pandemic in 2023 (Ministry of Finance Uganda, 2024). Attraction-level data demonstrate the continued dominance of the Basin's terrestrial parks: the Masai Mara recorded over 291,000 visitors in 2018, and all Kenyan parks combined registered 2.54 million visits in 2022 (Juma et al., 2020).

Across the Basin, tourism demand is structured around three core market tiers. Long-haul international visitors from Europe and North America remain the mainstay of high-value safari products (Bank of Tanzania, 2024). The intra-EAC market, however, constitutes the largest and most stable segment: **67%** of Uganda's

arrivals and **38%** of Tanzania's originate from neighbouring Partner States, particularly Kenya and Rwanda (East African Community & GIZ, 2021). Tanzania's 2023 exit survey further confirms that most repeat visitors come from Kenya and Uganda (Bank of Tanzania, 2024). Domestic tourism is equally critical, providing reliable demand during global disruptions; Kenya in particular benefits from a strong internal travel culture (East African Tourism Platform, 2025a).

Seasonal visitation follows the Basin's equatorial climate: peak flows align with the dry seasons (June–October, January–February), while the long rains (March–May) reduce mobility and suppress demand due to poor road conditions. The short rains (November–December) form a moderate-traffic shoulder season.

For riparian communities—many of whom live below USD 1.25/day—fishing remains the dominant livelihood but is increasingly threatened by environmental decline and over-exploitation (Drakenberg et al., 2007; Frontiers, 2022). The growth of lacustrine and community-based tourism offers a pathway toward a more diversified, service-oriented blue economy. By providing alternative income streams and reducing pressure on fisheries, tourism represents one of the most promising long-term opportunities for socio-economic transformation along the lake's shores.

6.6.5 Environmental Linkages, Challenges, and Sustainability

Tourism in the Lake Victoria Basin (LVB) is inseparable from the health of its ecosystems. The sector is simultaneously undermined by the Basin's accelerating degradation and contributes to some of the pressures driving it. Pollution, invasive species, and climate change now constitute immediate threats to the viability of lake-based tourism and, increasingly, to the long-term sustainability of the wider tourism economy.

Tourism's Environmental Footprint

Poorly regulated tourism development continues to add pressure to the Basin's fragile environment. Waste management remains a chronic challenge, especially around urban centres and islands, where inadequate collection systems have resulted in visible shoreline pollution and growing plastic loads (Monitor, 2021). Hotels and lodges add demand for water and energy, but the absence of effective wastewater treatment means many facilities contribute directly to nutrient loading in near-shore waters (Cooperation in International Waters in Africa, 2022).

Water Quality Decline

Deteriorating water quality represents the most direct and immediate threat to lake-based tourism. Untreated sewage from rapidly expanding towns, low sanitation coverage, and industrial and agricultural runoff have created extreme nutrient enrichment and widespread eutrophication (World Bank, 2021). The resulting harmful algal blooms damage aesthetics, undermine recreation, and pose health risks. In the Winam Gulf, toxin concentrations in 2022 exceeded WHO guidelines for both drinking water and recreational safety, leading to declining hotel patronage and closures of lakeside businesses (PubMed Central, 2022).

Invasive Species

Nutrient-rich waters also favour the spread of **water hyacinth**, which forms dense mats that obstruct navigation and restrict access to ports, islands, and fishing grounds (World Bank, 2023; Lund University, 2024). These blockages disrupt boat excursions and ferry routes—core components of the lake-based tourism experience.

Climate Change Risks

Climate change compounds these pressures and presents an existential risk to infrastructure-dependent tourism. Hydro-climate modelling projects a significant long-term decline in water levels, with the possibility that Lake Victoria could

lose its Nile outlet within decades and that major ports may become landlocked within a century (Beverly, 2019). Such shifts would strand billions of dollars in lakeside and port infrastructure and reshape tourism access and viability across the Basin.

Security Context

Security remains a pervasive challenge that affects visitor perceptions and investment risk. Kenya, Tanzania, and Uganda all face varying degrees of terrorism threat, violent crime, and periodic unrest, while Rwanda maintains a significantly lower risk profile. Despite these threats, tourism continues to grow, reflecting effective security management around major circuits and entrenched demand for high-value experiences.

Other Constraints

Infrastructure deficits—particularly poor roads and sanitation—continue to limit tourism development (County Government of Kisumu, 2018). Human–wildlife conflict, waste management failures, skill shortages, and governance gaps further constrain value creation and weaken local support for conservation and tourism (Royal Society Publishing, 2021; PwC Tanzania, 2024).

6.6.6 Policy, Legal, and Institutional Framework

Tourism governance in the Lake Victoria Basin (LVB) is shaped by a multilayered system that spans regional EAC frameworks, national policies, and community-level initiatives. While alignment between regional and national strategies has strengthened, implementation gaps—particularly around community empowerment—continue to limit the sector's sustainability and inclusiveness.

Regional and National Policy Alignment

The EAC provides the overarching basis for regional coordination. Article 115 of the EAC Treaty mandates joint tourism promotion and product development, operationalised through the EAC Tourism Marketing Strategy 2021–2025, which targets multi-destination circuits, and emerging frameworks on transboundary wildlife management and harmonised tourism standards (East African Community & GIZ, 2021; East African Community, 2025; Green Policy Platform, 2024). National policies mirror these priorities. Tanzania's tourism policy is aligned with EAC Vision 2050; Kenya anchors tourism within Vision 2030 and a regulatory strategy focused on quality assurance; and Uganda's development plans integrate regional instruments such as the Single Tourist Visa (Tourism Regulatory Authority Kenya, 2023; Ministry of Tourism Uganda, 2015).

Visa Regimes and Investment Incentives

Visa policies remain uneven across Partner States, influencing both competitiveness and regional visitor mobility. Kenya's shift to visa-free entry through a universal eTA system, Rwanda's globally open visa-on-arrival regime, and the e-visa platforms in Uganda and Tanzania provide relatively liberal access, whereas Burundi maintains more restrictive procedures. Investment incentives also vary: Kenya offers duty exemptions for tourism equipment; Tanzania provides capital allowances and VAT deferrals; Rwanda offers tax holidays for large projects; and Uganda maintains concessional import duties (Rwanda Revenue Authority, 2021).

Institutional Roles

Regionally, the EAC Secretariat leads policy harmonisation, while the Lake Victoria Basin Commission (LVBC) coordinates sustainable development at basin scale, linking environmental management to tourism policy (Lake Victoria Basin Commission, 2021). National tourism boards and wildlife authorities implement marketing, product development, and site management, increasingly collaborating under the unified "Visit East Africa" platform at global fairs.

Community-Based Tourism (CBT)

CBT is widely promoted as the main mechanism for achieving inclusive, conservation-linked tourism in the Basin. It aims to provide alternative livelihoods, strengthen local stewardship of natural assets, and retain revenue within communities (MDPI, 2024d; PubMed Central,

2023a). Successful models—such as Mabamba Bay's community-run wetland tours and the community-linked initiatives around Rubondo Island—demonstrate the viability of CBT for sensitive lake and island ecosystems (UN-Water, 2019). However, many enterprises face structural barriers, including poor infrastructure, skills gaps, and weak market linkages; in Uganda, for instance, most souvenirs sold to tourists are imported, reflecting a failure to integrate local artisans into tourism value chains (ILO, 2025).

Strategic Implications

The Basin's most resilient tourism models are conservation-focused and rooted in local participation. While regional and national policies explicitly support CBT, implementation lags behind ambition. Strengthening community skills, market access, and governance mechanisms is therefore essential for translating policy commitments into equitable, sustainable tourism outcomes across the LVB.

6.6.7 Recommendations

Tourism in the Lake Victoria Basin can only achieve long-term growth if environmental restoration, climate-resilient planning, strong institutions, and genuine community participation are placed at the centre of development efforts. The recommendations below outline the core priorities required to safeguard the Basin's ecological assets, strengthen competitiveness, and ensure inclusive local benefits.

- **Prioritise environmental infrastructure** by rapidly expanding wastewater and solid-waste treatment systems in lakeside towns and tourism hubs to break the pollution–tourism decline cycle and protect ecological assets.
- **Develop a climate-resilient, lake-wide tourism master plan** led by LVBC to guide investment, zoning, and infrastructure, with all projects stress-tested against long-term water-level and climate projections.
- **Mobilise public–private partnerships** to close critical infrastructure gaps—especially roads, ferry systems, and island airstrips—through clear, bankable PPP frameworks.
- **Promote integrated, multi-country circuits** that combine flagship wildlife destinations with lake-based attractions, leveraging the Basin's strong air connectivity and intra-EAC visitor market.
- **Make community-based tourism the preferred model** for lake and island development, backed by investments in skills, market access, and basic infrastructure to ensure communities retain a meaningful share of tourism revenues.
- **Strengthen data systems, local value chains, and digital competitiveness** by expanding basin-specific tourism monitoring, supporting women and youth entrepreneurs, and investing in modern digital marketing and booking platforms.

6.7: Water Use Projections and Coping Strategies

Water use projections and coping strategies are strategic to securing the Lake Victoria Basin's long-term social, economic, and ecological stability. Section 6.7 section examines how the basin's climate-sensitive Net Basin Supply interacts with rapidly rising, spatially concentrated demands. It reviews the dominant water-using sectors, presents a basin-wide estimate of current consumptive demand, and projects future demand to 2050 under the Regional Vision Scenario, before assessing key sectoral trade-offs and priority investment responses for resilient, efficient water use.

6.7.1 Renewable Water Availability and the Basin's Hydrological Constraints

Despite its immense storage of about 2,760 BCM, Lake Victoria's water security is governed not by its volume but by its renewable flux, determined overwhelmingly by the balance between direct rainfall and open-water evaporation. This makes the lake one of the world's most atmosphere-dependent freshwater systems and highly sensitive to climatic variability.

As explained in Chapter 4, approximately 80-82% of all inflows originate from rainfall directly over the lake's 68,800 km² surface. Annual rainfall inputs average 100–117 BCM, while evaporation removes 105–110 BCM, representing three-quarters of all losses (LVBC, 2022; Tate et al., 2004; Vanderkelen et al., 2018). River inflows contribute just 18–24 BCM per year, underscoring that the manageable portion of the water balance lies primarily in the catchment, not the lake surface.

When rainfall inputs and evaporation are combined with river inflows, the long-term Net Basin Supply (NBS)—the renewable water actually available for abstraction—averages approximately 20–30 BCM per year (Tate et al., 2004; NBI, 2021; LVBC, 2022). This aligns with the long-term average outflow of 23.5–33 BCM/year through the Nalubaale–Kiira hydropower complex, which equilibrates to NBS over extended periods. Climate variability drives sharp deviations from this mean as seen 2019-2020 and 2023-2024.

6.7.2 Major Water Use Sectors

Water use in the Lake Victoria Basin (LVB) is dominated by three interlinked sectors: agriculture as the principal consumptive user, hydropower as the primary non-consumptive and flow-regulating user, and domestic–industrial supply as the fastest-growing demand. Together, these sectors define the basin's core allocation pressures and governance challenges.

Agriculture: The Unfinished Transition

Agriculture remains the economic backbone of the LVB, supporting about 80% of the rural population. Yet despite the basin's substantial water endowment, production remains overwhelmingly rain-fed and increasingly exposed to climate variability. Although national strategies—such as Kenya's National Water Master Plan 2030 and Tanzania's National Irrigation Master Plan—prioritize irrigation expansion, implementation has lagged far behind ambition.

The gap between irrigation potential and actual development is pronounced. In Kenya's lake basin, which occupies only 8.5% of national land area but holds over half of its renewable freshwater resources, irrigation potential is estimated at about 200,000 ha (Republic of Kenya, 2013; NBI, 2016). Yet utilization remains minimal. The Lower Kuja Scheme, for example, has developed only 7,500 of its gazetted 19,000 acres, with less than 5,400 acres currently under production (NIA, 2024). Similar under-development persists in Tanzania, where large schemes in the Bugwema, Manonga, and Isanga

valleys remain largely at pilot or feasibility stage despite proven suitability for high-value crops (FutureWater, 2008).

Where irrigation has expanded, it is concentrated in highly water-intensive sugarcane and rice systems. The Kagera Sugar estate in Tanzania applies advanced center-pivot irrigation across 26,000 ha, achieving high control but generating a substantial localized abstraction footprint (Kagera Sugar, 2024). In Rwanda, the Kabuye Sugar Works records a specific water demand of 29 m³ per ton of sugar—above recommended best practice—indicating scope for major efficiency gains (Mwali et al., 2017). In Kenya's Kano Plains, rice schemes dominate abstraction, but aging infrastructure constrains performance; pump efficiency at Ahero averages only 47%, with more than half of input energy lost to mechanical inefficiencies (Onyango & Kiptanui, 2024).

Domestic and Municipal Water Supply

The domestic sector is shaped by rapid, largely unplanned urbanization in lakeside cities—Kampala, Kisumu, and Mwanza—placing intense pressure on municipal utilities to expand supply. These cities function as major point-source abstractors, drawing directly from the lake or key tributaries, often close to their own wastewater discharge locations.

- **Kisumu (Kenya):** KIWASCO operates a dual-source system to manage energy costs. The Dunga plant (44,000 m³/day) depends on energy-intensive lake pumping, while the Kajulu plant (36,000 m³/day) uses gravity flow from the Kibos River system (KIWASCO, 2023). Although this diversification reduces exposure to high electricity tariffs, supply still falls short of growing demand exceeding 55,000 m³/day.
- **Mwanza (Tanzania):** Mwanza depends entirely on Lake Victoria. Historically supplied by the Capri Point intake (90,000 m³/day), capacity was expanded in 2024 through Phase I of the Butimba project, adding 48,000 m³/day and raising total capacity to about 138,000 m³/day. This remains below estimated daily demand of 172,000 m³/day (The Citizen, 2025).
- **Kigali (Rwanda):** Although located in the upper catchment, Kigali faces severe supply constraints driven by high system losses, with NRW peaking at 41.8% (JICA, 2024). The Kigali Water Supply Master Plan projects demand exceeding 525,000 m³/day by 2050, requiring major new bulk water abstractions from the Nyabarongo system (WASAC, 2021).

Industry and Mining: The Enclave Water Economy

The LVB hosts a distinct "enclave" water economy dominated by large extractive industries, especially in Tanzania's Lake Victoria Goldfields. Unlike municipal users, these operations rely on autonomous, high-capacity abstraction, storage, and treatment systems.

- **Geita Gold Mine (AngloGold Ashanti):** Operates a dedicated 25-km pipeline drawing directly from Lake Victoria at Nungwe Bay to support ore processing and dust suppression, powered by a 36-MW captive diesel plant (AngloGold Ashanti, 2022).
- **North Mara Gold Mine (Barrick):** Following regulatory action on tailings overflow risks, the mine commissioned advanced treatment and recycling facilities (up to 40,000 m³/day), shifting part of its water balance from net abstraction toward reuse (Barrick, 2024; Mining Weekly, 2013).
- **Williamson Diamond Mine:** Relies on large industrial impoundments; the 2022 tailings dam failure exposed the scale of water volumes involved and the associated environmental risks (IPIS, 2025).

Beyond mining, agro-processing adds localized pressure. In Kenya, paper milling (Webuye) and sugar factories (Chemelil, Muhoroni) are major riparian abstractors, while Rwanda's Kabuye Sugar Works diverts Nyabarongo flows for both irrigation and factory cooling (Mwali et al., 2017).

Fisheries (Aquaculture) as a Water Use Sector

While capture fisheries depend on the lake's biological productivity, cage aquaculture increasingly uses its physical space and assimilative capacity. Rapid cage expansion in the Jinja and

Mwanza Gulf areas has introduced new spatial competition with navigation routes and municipal intake protection zones. Although volumetric consumption is negligible, cage culture is a significant user of the lake's water-quality attributes, particularly dissolved oxygen and flow conditions (LVFO, 2016).

6.7.3 Current Consumptive Water Demand Estimation

Methodology

As part of the State of Basin Report (SoBR) preparation, total consumptive water demand in the Lake Victoria Basin (LVB) was estimated using bottom-up inputs from Partner States. The assessment integrated data from sub-catchment development plans, human population, livestock populations, wildlife populations (in conservation areas), irrigated farm areas and crop types, aquaculture facilities, and existing industrial activities and production levels. These physical drivers were converted into water demand using sector-specific per-capita or per-unit consumption coefficients, adjusted for prevailing water-use efficiencies. This approach ensures that estimated demands reflect actual patterns of economic production, settlement, and resource use across the basin, rather than relying solely on national averages.

Consumptive demand

Total basin-wide consumptive water demand for 2020 estimated under this study is 2,408 million cubic metres per year (MCM/year) (Table 6-20). This represents only about 8% of the Net Basin Supply of approximately 30 billion cubic metres (BCM), indicating that, at the aggregate scale, the basin remains hydrologically resilient. However, this apparent abundance masks significant spatial concentration of demand and emerging localised pressure in several sub-catchments.

Water demand is strongly dominated by the domestic and municipal sector (including industry), which accounts for 57.2% of total consumptive use. Irrigation follows as the second largest user at 27.7%, while livestock, wildlife, fisheries, and inter-basin transfers together contribute relatively minor shares (Figure 6-33). This structure reflects the basin's rapid urbanisation, expanding industrial base, and increasing emphasis on irrigated high-value agriculture.

Table 6-20. *Estimates of consumptive water demand (MCM/year) in the LVB sub-basins in 2020*

Country	Sub-basin	Irrigation	D.S.	Domestic & Industrial	D.S.	Livestock	D.S.	Wildlife & Fisheries	D.S.	Transfers Out	D.S.	Total Demand MCM/year)
Uganda	Northern Shore (A)	1.4	10	164	10	0.6	5			175.3		341.3
Tanzania	Isanga	120	3	160.2	4	2.6	5			21.9		304.7
Kenya	Nzoia	16.6	1	160.3	1	15.7	1	6.9	1	12.4	1	211.9
Tanzania	Lower Kagera (URT)	52	3	131.2	4	1.7	5			0		184.9
Tanzania	Ma-gogo-Moame	75	3	85.7	4	1.1	5			0		161.8
Kenya	North Awach	73	2	64.7	2	5.7	2	2.5	2	0	2	145.9
Kenya	Gucha Migori	22.9	2	101.3	2	20.2	2	1.5	2	0	2	145.9
Tanzania	Simiyu	52	3	84.9	4	2.2	5			0		139.1
Kenya	Nyando	64.1	2	51.3	2	6.4	2	3.5	2	0	2	125.3
Kenya	Mara-Mori (URT)	35	3	54.2	4	1.2	5			0		90.4
Uganda	Northern Shore (B)	13.5	10	59	10	0.3	5			4.8		77.6

Country	Sub-basin	Irrigation	D.S.	Domestic & Industrial	D.S.	Livestock	D.S.	Wildlife & Fisheries	D.S.	Transfers Out	D.S.	Total Demand MCM/year)
Tanzania	Grumeti-Mbalageti	15	3	59.9	4	1.7	5			0		76.6
Kenya	Yala	19.3	1	33.2	1	5.3	1	2.1	1	0	1	59.9
Kenya	Sondu	12.7	2	32.3	2	7.3	2	4	2	0	2	56.3
Uganda	Katonga	0.1	9	27.5	9	9.7	9	16.4	9	0		53.7
Burundi	Akanyaru	21.2	7	10.8	7	0.6	5			0		32.6
Kenya	Middle Mara (KE)	2.7	2	14	2	12.9	2	2	2	0	2	31.6
Burundi	Upper Kagera (BUR)	11.6	6	17.6	6	1	5			0		30.2
Uganda	Rwizi (Bukora)	3.5	8	17.8	8	5	8			0		26.3
Rwanda	Upper Akagera	16	7	9.8	7	0.4	5			0		26.2

Country	Sub-basin	Irrigation	D.S.	Domestic & Industrial	D.S.	Livestock	D.S.	Wildlife & Fisheries	D.S.	Transfers Out	D.S.	Total Demand MCM/year)
Rwanda	Lower Nyabarongo	8	7	12	7	0.6	5			0		20.6
Kenya	South Awach	7.8	2	2.4	2	0.5	2	0.5	2	0	2	11.2
Rwanda	Upper Nyabarongo	1.2	7	8.4	7	0.5	5			0		10.1
Kenya	Sio	3.2	1	3.9	1	1.8	1	0.9	1	0	1	9.8
Rwanda	Lower Akagera	8.4	7	0.9	7	0.5	5			0		9.8
Kenya	Upper Mara (KE)	1	2	4.6	2	2.7	2	0.5	2	0	2	8.8
Rwanda	Muvumba	5	7	0	7	0	5			0		5.7
Uganda	Muvumba	5	7	0	7	0	5			0		5.7
Burundi	Mukungwa	0	7	3.7	7	0.4	5			0		4.1
Totals		666.9		1376.5		109.4		40.8		214.4	17	2,408

D.S = Data Sources:

1. (Kenya Water Resource Authority, Aurecon, 2020a)
2. (Kenya Water Resource Authority, Aurecon, 2020b)
3. (Tanzania Ministry of Water and Irrigation, Nippon Koei, 2018)
4. (Tanzania Ministry of Water and Irrigation, Nippon Koei, 2018), dis- aggregated with sub-basin population.
5. Livestock densities from (Food and Agriculture Organisation (FAO), 2024). Water demands estimated by study team.
6. Country-wide demands from (Food and Agriculture Organisation (FAO), 2024). Scaled to catchment by study team.
7. (Rwanda Natural Resources Authority, 2015)
8. (Uganda Ministry of Water and Environment, 2020)
9. (Uganda Ministry of Water and Environment, 2021)
10. Study Team Estimate

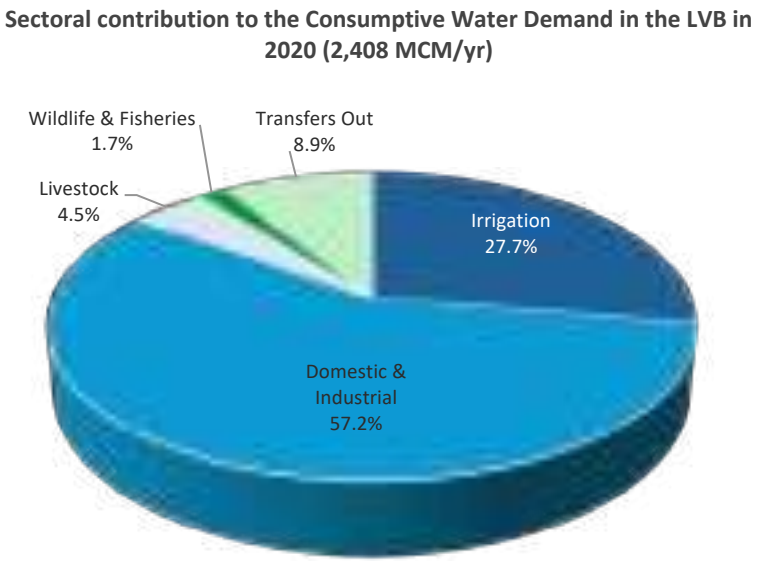


Figure 6-33. *Sectoral composition of the total consumptive water demand in the Lake Victoria Basin in 2020*

Spatial Distribution of Water Demand

Water demand is highly uneven across the basin. Kenya and Tanzania together account for 1,774 MCM/year, or 73.3% of total basin demand, reflecting their large populations, extensive irrigation development, and concentration of urban and industrial centres. Uganda contributes 505 MCM/year, while Rwanda and Burundi together account for only 139 MCM/year, representing less than 6% of total demand (Figure 6-33).

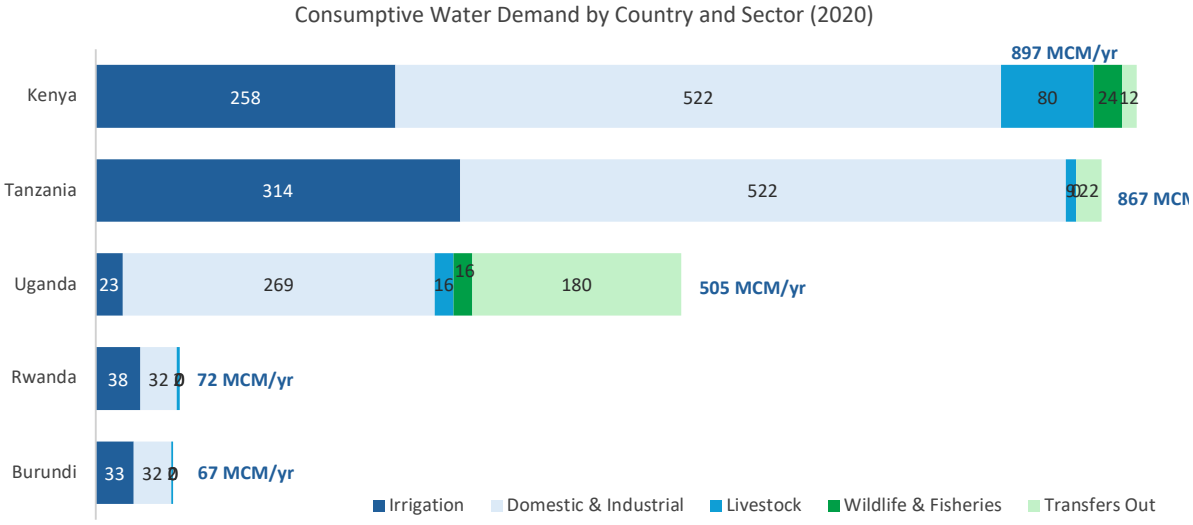


Figure 6-34. *Sectoral composition of the water demand by the LVB countries.*

At the sub-catchment scale, the largest consumptive demands are concentrated in Kenya and Tanzania **(Figure 6-35)**. The major exception is the Northern Shoreline Streams sub-catchment in Uganda, which records the highest single sub-basin water demand in the entire LVB. This reflects the presence of Uganda's largest urban and industrial agglomeration—Kampala, Entebbe, and Jinja, alongside rapidly

growing satellite towns such as Mukono, Kajjansi, and Lugazi. These areas combine very high population densities, intensive industrial manufacturing, and large irrigation schemes for high-value crops, notably sugarcane and floriculture, resulting in exceptional localised water demand.

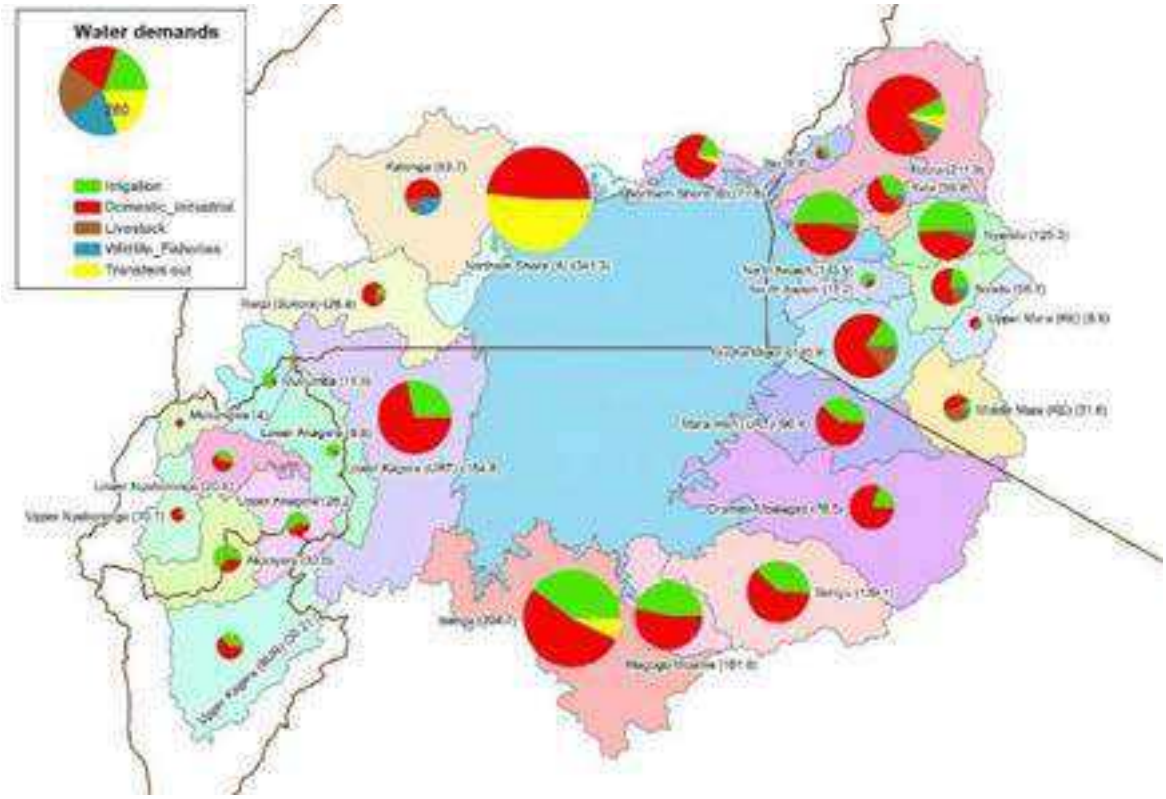


Figure 6-35. *Consumptive water demands in the LVB sub-basins (2020).*

From the above synthesis, the high and low demand zones are the following:

- **High-Demand Zones:** The Northern Urban–Industrial Axis (Kampala–Jinja) forms the basin's largest demand corridor, combining rapidly rising municipal consumption—projected to exceed 530,000 m³/day by 2040—with a dense industrial base (NWSC, 2024). The Eastern Irrigation Belt (Kisumu–Kano Plains) is defined by rice and sugar production, where clustered schemes drive highly seasonal surface-water abstraction and intensify competition with environmental flows during dry periods (NIA, 2024). In the south, the Mwanza–Geita Extractive Node is characterized by extreme point-source demand from large mining operations that rely on dedicated pipelines and high-volume abstracted flows, largely disconnected from the surrounding rural water economy (AngloGold Ashanti, 2022).
- **Low-Demand / High-Potential Zones:** The Kagera Transboundary Aquifer, spanning Burundi, Rwanda, and Tanzania, represents a major strategic reserve, with vast storage (~50 BCM) but negligible current abstraction (NBI, 2025). Likewise, the deep offshore waters of Lake Victoria remain largely untapped for supply due to high intake costs, despite offering better raw-water quality than polluted nearshore zones.

6.7.4 Projection of Future Water Demand in the Lake Victoria Basin

Scenario-Based Assessment of Future Consumptive Water Demand

Future water demand in the Lake Victoria Basin (LVB) was projected using a scenario-based growth approach derived from the East Africa Water Scenarios to 2050 study (IIASA, 2021). The method links demographic change and socio-economic development pathways to sectoral water-use trajectories, consistent with regional long-term planning under EAC Vision 2050.

Population growth is the primary driver of increasing water demand across all sectors, while rapid urbanisation (4–5% per year) strongly reshapes the distribution of demand—shifting water use progressively from agriculture toward domestic, municipal, and industrial (DMI) sectors. Among the alternative scenarios assessed in the regional study, this assessment adopts the Regional Vision Scenario (RVS), which represents the EAC's preferred development pathway. The RVS assumes moderate population growth; improved education and health outcomes; technological progress; reduced water-use intensity and fossil-fuel dependence; and a transition toward near parity between rural and urban populations by 2050.

For this edition of the State of the Basin Report, the sector-specific growth rates under the RVS were applied directly to the baseline sectoral water demand estimates presented in Section 4.4.1. This produced a consistent, basin-wide projection of future consumptive water requirements. Using this method, total consumptive water demand in the Lake Victoria Basin is projected to rise from approximately 2,400 MCM/year in 2020 to about 5,400 MCM/year by 2050. The fastest growth occurs in the domestic and industrial sector, where demand is projected to increase by a factor of about 2.6, reflecting rapid urban expansion and rising service levels ***(*Figure 6-36).**

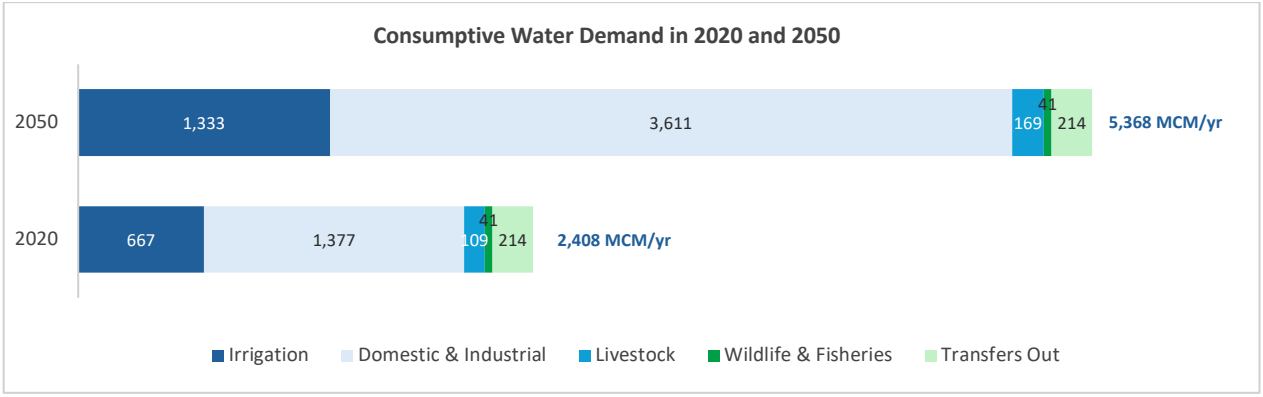


Figure 6-36. *Consumptive water demands in eh LVB in 2020 and 2050.*

The projected total consumptive water demand of 5,400 MCM/year by 2050 is substantially lower than the IIASA RVS estimate of 10,600 MCM/year for the same horizon. This difference arises mainly from the use of more recent national masterplan and catchment-based demand data, and from projecting growth from a 2020 baseline, rather than the 2010 base year used in the IIASA assessment. Despite the lower absolute estimate, the core conclusion remains unchanged: pressures on water availability will continue to intensify in parts of the Lake Victoria Basin, with the most severe seasonal scarcity expected during the dry month of July, particularly in the Kagera, Mara, and Simiyu sub-basins.

The Supply-Demand Nexus under Climate Change

Comparing aggregated demand against availability reveals a precarious future balance.

- **The 2050 Deficit Scenario:** Current modeling by the Nile Basin Initiative suggests that if all planned irrigation and hydropower projects are implemented without coordination, the basin could face a water deficit of 40–45 BCM/year by 2050 (NBI, 2016). This "Vision Scenario" implies that demand would outstrip the renewable Net Basin Supply (NBS), leading to a structural drawdown of Lake Victoria levels.
- **Climate Variability as a Disruptor:** Climate change scenarios for East Africa predict a "wetter but more variable" future. While average rainfall may increase, the intensity of extreme events (floods and droughts) will rise. The 2019-2020 rising lake levels (driven by the Indian Ocean Dipole) demonstrated the system's volatility, flooding infrastructure that was previously left high and dry by the 2005 drought (Frontiers in Water, 2021). This variability makes "firm yield" planning difficult; infrastructure designed for average flows may fail during extremes.
- **Economic vs. Physical Scarcity:** The IIASA "Water for Growth" study highlights that for the next decade, the basin faces economic water scarcity (lack of infrastructure to move water to where it is needed) rather than physical scarcity (lack of water source). However, by 2050, physical scarcity will emerge in specific sub-basins like the Mara and Nyando if efficiency does not improve (IIASA, 2021).

6.7.5 Strategic Responses and Sectoral Trade-offs

To bridge the emerging supply-demand gap, the basin must adopt aggressive coping strategies that acknowledge the trade-offs between competing users.

Sectoral Trade-offs and Optimal Use:

- **Hydropower vs. Irrigation:** The most critical future trade-off is between maintaining high lake levels for the Nile Cascade hydropower (Uganda) and abstracting water upstream for irrigation (Kenya/Tanzania). Optimal use analysis suggests that high-value industrial crops (like greenhouse horticulture) offer better "dollar per drop" returns than water-intensive/low-value crops like flood-irrigated rice, yet food security policies often favor the latter.
- **Allocating for Environment:** The concept of "Environmental Flows" (E-Flows) must be operationalized. The Mara River Water Allocation Plan (WAP) sets a precedent by legally prioritizing the river's ecological reserve (for the Serengeti-Mara ecosystem) over irrigation withdrawals during low-flow months (Winrock, 2021).

Offsetting Impacts on Water Quality:

- A key trade-off arises between abstraction and water quality. Industrial and municipal users continue to rely on the lake's assimilative capacity to dilute pollution, yet this reduces the volume of water that remains usable for domestic supply or industry. Treating wastewater at source is far more cost-effective than relying on dilution, and strict enforcement of polluter-pays principles is necessary as demand and pollution loads rise.
- **Cleaner Production in Industry:** Industries are adopting "zero liquid discharge" and closed-loop recycling. The North Mara Gold Mine's investment in a 40,000 m^3/day water treatment plant to recycle tailings water serves as a model for decoupling industrial growth from freshwater abstraction (Barrick, 2024).

6.7.6 Recommendations for Investment

To secure the basin's water future, investment must shift from simple abstraction to complex management.

1. Mobilizing Climate Finance: The basin's

high climate vulnerability makes it well positioned to access major adaptation funds. A regional approach—such as an LVBC-led Basin Resilience Program—would aggregate national priorities and emphasize transboundary benefits, strengthening the case for large-ticket financing from the GCF and Adaptation Fund. Priority investments include climate-smart agriculture, wetland restoration, and improved early warning systems. The HIGHWAY project illustrates the economic returns of climate resilience, achieving a benefit–cost ratio of 16:1 (WMO, 2020).

2. **Economic Investment in Storage:** Shift from run-of-river reliance to multi-purpose storage. Developing small-to-medium storage dams in the catchment (e.g., upstream Nyando or Kagera) will buffer the seasonal variability, securing water for irrigation during dry months without depleting environmental flows.

3. **Restoring natural infrastructure is equally critical.** Wetlands and water towers function as the basin's primary buffer against climate variability, moderating floods, supporting dry-season flows, and improving water quality. Nature-based solutions—including wetland rehabilitation and protection of the Mau Forest, Mt. Elgon, and Kagera headwaters—offer more cost-effective resilience than large grey structures, with comparable benefits for flood attenuation and water purification (World Bank, 2022).

4. **Blended Finance for Water and Sanitation Infrastructure:** Public budgets alone cannot deliver the infrastructure required—sanitation needs in secondary towns are estimated at US$1.9 billion (World Bank, 2023). Blended finance structures, supported by development partners, can de-risk private investment in water supply and wastewater treatment. Public–private partnerships for bulk water systems, industrial effluent treatment, and decentralized sanitation can leverage user fees and polluter charges to secure long-term revenue streams.

5. **Investing in the Blue Economy:** Higher economic returns can be achieved without increasing water abstraction by prioritizing value addition. Reducing post-harvest losses in fisheries and expanding cold-chain and processing capacity could triple economic returns from existing catch levels (Natugonza et al., 2022). Upgrading transport infrastructure—ports in Kisumu, Mwanza, and Port Bell—would strengthen regional trade and reduce transport emissions. Recent investments in maritime communications (LVBC, 2016) should be complemented with port modernization to unlock the basin's full blue economy potential.

6. **Social Investment in Efficiency:** Scale up investments in Non-Revenue Water (NRW) reduction. Reducing physical leaks in Kisumu and Kigali from ~40% to 20% is the most cost-effective "new source" of water available, yielding immediate social benefits **without new environmental impacts.**

7. **Governance Investment:** Strengthen the Lake Victoria Basin Commission's mandate to monitor and enforce the "Agreed Curve". Investing in the LVB Water Information System (WIS) is a prerequisite for evidence-based trade-offs between sovereign states.

8. **Strengthening the Water Information System (WIS):** Financing is currently constrained by uncertainty about water availability, quality, and hydrological risks. A fully operational Water Information System, building on the platform developed with KfW support, would provide open-access, real-time data on water resources and abstraction. Embedding WIS as a core LVBC function reduces investor risk premiums and improves the bankability of water-related projects.

The Lake Victoria Basin is transitioning from a resource frontier to a regulated hydraulic machine. The challenge for 2025-2050 is not just building pipes and pumps, but building the institutions and logic to manage the trade-offs between a thirstier economy and a finite, variable lake.

Chapter 7

CLIMATE CHANGE, VULNERABILITY, AND RESILIENCE



SUMMARY (CHAPTER 7)

Chapter 7 focuses on the scientific evidence, vulnerabilities, and responses to climate change in the Lake Victoria Basin (LVB). Its objective is to establish an authoritative account of observed and projected climatic changes, identify socio-ecological systems most at risk, and assess the adequacy of ongoing adaptation and mitigation measures. The chapter ultimately seeks to inform basin-wide policy and investment decisions aimed at building resilience and safeguarding livelihoods.



Scientific basis: what is changing

The Basin is warming fast, with rising temperatures and more heat extremes. The Lake Victoria Basin has warmed by about +0.2–0.3 °C per decade since 1960, slightly above global average of 0.20 – 0.28°C/ decade.



Impacts and risks across systems

Lake levels and river regimes are more "flashy"; groundwater and water quality are stressed by hotter conditions, heavier downpours, and degraded catchments.



Enabling framework: policy, governance, and finance

Ambition is high but institutions and finance are stretched. Countries align with EAC climate change frameworks and NDCs, yet cooperation is fragmented, agencies face "mandate–capacity" gaps, and financing needs to 2030 (> USD 130 bn) far exceed current flows.



Policy Recommendations

Mainstream climate in development – Integrate NAPs, NDCs, and sector plans into national budgets and planning frameworks.

Invest in blended grey–green infrastructure – Prioritize projects that combine engineered ("grey") systems with nature-based ("green") solutions for flood control, water storage, drainage, and urban resilience.

Key Messages

Scientific basis: what is changing

1. **The Basin is warming fast,** with rising temperatures and more heat extremes. The Lake Victoria Basin has warmed by about +0.2–0.3 °C per decade since 1960, slightly above global average of 0.20 – 0.28°C/ decade. Nights are warming faster than days—intensifying evapotranspiration and heat stress for people, crops, and livestock.
2. **Rainfall reliability is deteriorating** despite modest increased in annual rainfall. Short rains (OND) are strengthening while long rains (MAM) are faltering; rainfall arrives in shorter, more intense bursts separated by longer dry spells.

Impacts and risks across systems

3. **Water resources are becoming more volatile**. Lake levels and river regimes are more "flashy"; groundwater and water quality are stressed by hotter conditions, heavier downpours, and degraded catchments.
4. **Ecosystems and biodiversity are under strain.** Warming waters and longer stratification expand low-oxygen zones; wetlands/forests are degraded; invasive species thrive.
5. **Human health and services face compounded risks.** Floods contaminate water supplies; warming extends malaria suitability; heat and food insecurity rise.

6. **Disasters are costly and escalating.** 2020–2024 direct economic losses were large across all Partner States; agriculture is most affected, and infrastructure damage is mounting.
7. **Climate impacts amplify poverty and drive internal migration.** Cumulative sector impacts increase displacement toward lakeshore and urban areas, straining services and governance.

Enabling framework: policy, governance, and finance

8. **Ambition is high but institutions and finance are stretched.** Countries align with EAC climate change frameworks and NDCs, yet cooperation is fragmented, agencies face "mandate–capacity" gaps, and financing needs to 2030 (> USD 130 bn) far exceed current flows.
9. **Finance must broaden and de-risk**. Multilateral funds remain central; blended-finance and PPPs, green taxonomies, and bonds can crowd-in private capital.
10. **Decisions outpace data.** Downscaled forecasts, localized impact analytics, and open data remain patchy across the Basin.

Adaptation: what works and where the gaps are

11. **Proven solutions exist.** People-centred early warning (HIGHWAY) cut storm-related deaths ~30% and delivers high benefit-cost returns; community-driven Ecosystem Based Adaptation (EbA) has boosted yields and reduced erosion.
12. **But progress is uneven.** Chronic under-financing, fragmented mandates, weak data/knowledge services, and a "pilot project trap" limit scale.

Mitigation

13. **Emissions are low globally but AFOLU-dominated.** Basin countries emit ~290–320 $MtCO_2e$ (<1% of global), with agriculture, forestry and land use as the largest source.

Policy Recommendations

National-Level Priorities – Led by Partner States

14. **Mainstream climate in development – Integrate NAPs,** NDCs, and sector plans into national budgets and planning frameworks.
15. **Invest in blended grey–green infrastructure** – Prioritize projects that combine engineered ("grey") systems with nature-based ("green") solutions for flood control, water storage, drainage, and urban resilience.
16. **Build resilient landscapes and livelihoods** – Expand climate-smart agriculture, sustainable forestry, and catchment restoration.
17. **Enforce climate laws and accountability** – Operationalize national climate acts, MRV systems, and environmental compliance mechanisms.
18. **18. Expand devolved finance** – Scale up county/district climate funds to reach communities, women, and youth.
19. **Invest in knowledge and innovation** – Strengthen hydromet services and merge scientific and Indigenous and Local Knowledge.
20. **Advance low-carbon transitions –** Promote renewable energy, clean cooking, and sustainable land and peatland management.

Regional-Level Priorities – Coordinated by EAC Secretariat and LVBC

21. **Create a regional climate and knowledge hub** – Support Partner States through an LVBC-led platform for data, modelling, and decision support.
22. **Align and reinforce national frameworks** – Coordinate a basin-wide adaptation and mitigation programme that strengthens and complements national NAP and DRR implementation.
23. **Mobilize regional finance** – Establish a project-preparation and blended-finance facility to co-finance national and transboundary infrastructure, including grey–green systems.



Homes along the shoreline of Lake Victoria flooded by rising water levels in 2020 (Credits: EOS science magazine)

24. **Scale up ecosystem restoration** – Coordinate joint LVBC–LVFO–NELSAP initiatives for wetlands, forests, and catchments that buffer national investments.
25. **Strengthen regional early-warning systems** – Expand HIGHWAY and CREWS into a basin-wide interoperable network serving local and national institutions.
26. **Foster learning and capacity exchange** – Institutionalize an annual Lake Victoria Climate Forum to share knowledge, track progress, and align policies.

Key State Indicators – Climate Change (2025)

Strategic & Thematic Areas	Indicator / Metric	Value / Range (2025)
C1 Climate and extreme weather		
C1.1 Climate trends	Average surface temperature	~7–24 °C
	Average annual rainfall	~530–2,400 mm
	Average annual evapotranspiration	~600–1,600 mm
	Historical temperature change (1960–2024)	Warming of ~0.2–0.3 °C per decade
	Historical rainfall change (1960–2024)	Modest wetting trend of ~1–2 % per decade
C1.2 Floods	Frequency of major flood events	1–2 events per year
	Change relative to 1950s baseline	~3× increase
C1.3 Droughts	Frequency of major drought events	1–2 events per year
	Change relative to 1950s baseline	~3× increase
C1.4 Differentiated impacts on women and men	Gender Equality Indicator	~52–67 %
C1.5 Climate change predictions and impacts	Projected maximum temperature change by 2100	Up to +3.6 °C
	Projected minimum temperature change by 2100	Up to +4.5 °C
	Projected mean annual rainfall change by 2100	+10–15 % (relative to 1985–2014 baseline)
	Projected hydrological extremes	Increased frequency of floods and droughts
C2 Climate resilience		
C2.1 Climate change adaptation	Status of national climate policies and NAPs	Policies and NAPs in place in all Partner States
	Status of adaptation financing	Underfunded
C2.2 Climate change mitigation	Total annual GHG emissions (LVB Partner States)	~290–320 $MtCO_2e$
	Share of global emissions	<1 %
	Largest emitting sector	Agriculture, forestry and land use (AFOLU)
	Key mitigation measures	Afforestation, wetland restoration, climate-smart agriculture, renewable energy expansion

7.1 The Scientific Basis: Observed and Projected Climate Change

This section provides the scientific foundation for understanding climate change in the Lake Victoria Basin. It draws on historical records, observations, and model projections to describe both **observed trends** and **future scenarios** of temperature, rainfall, and hydrological extremes. Section 7.1.1 analyses past and current changes, while 7.1.2 outlines projected conditions under different global emission pathways, together forming the basis for assessing climate risks and guiding adaptation planning.

7.1.1 Observed Climate Trends and Manifestations

Temperature Trends

The LVB has experienced a clear and accelerating warming since the mid-20th century, in line with wider African and global patterns (Figure 7-1). Average temperatures have risen by about 1 °C since the 1920s, with a warming rate of 0.2–0.3 °C per decade between 1960 and 2020 (McSweeney et al., 2010; World Bank, 2021; WMO, 2024). This warming rate is slightly higher than the global warming average of 0.20 – 0.28°C/ decade (NOAA, 2024). The decade 2015–2024 is the warmest on record for Africa (WMO, 2025), marking a new climatic baseline for the basin.

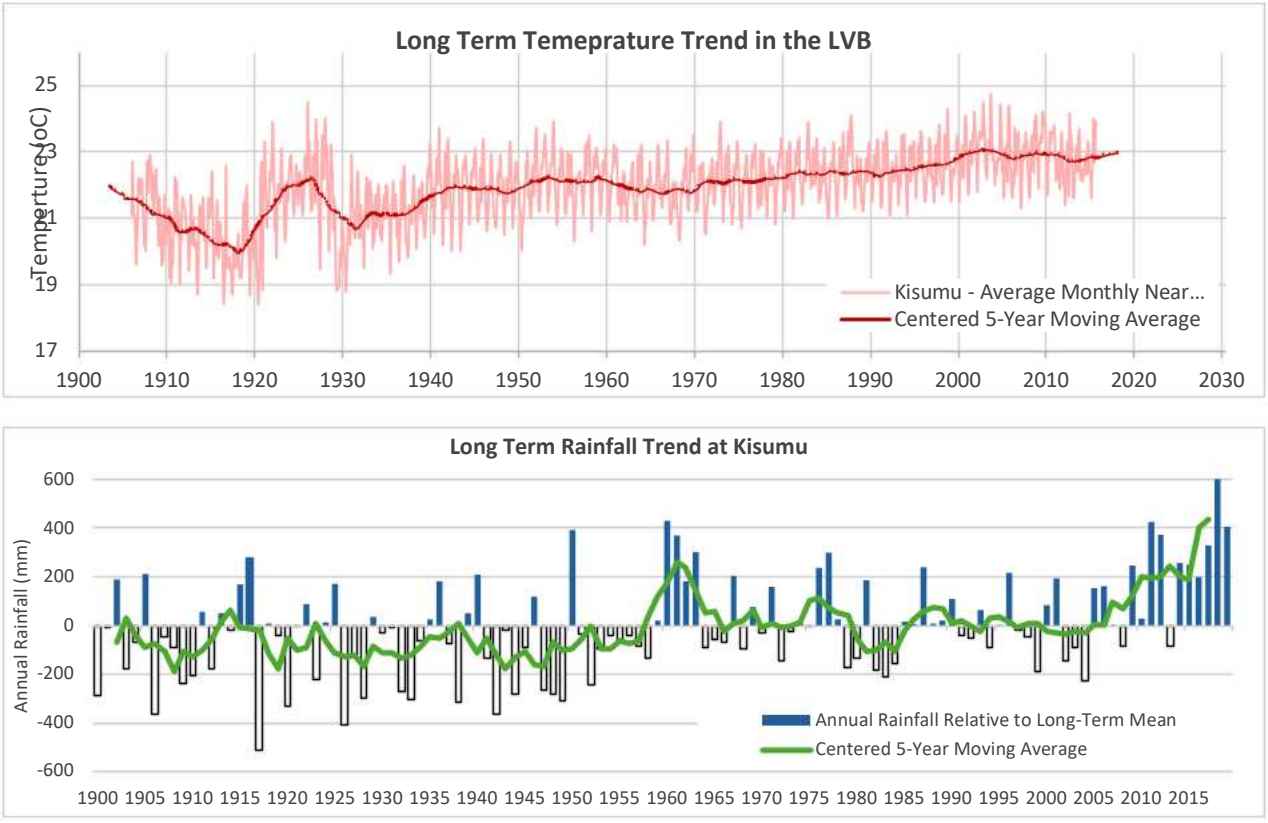


Figure 7-1. *Long term temperature and rainfall trends at Kisumu in the Lake Victoria Basin (CRU TS v4.09, 2025). The long term average annual rainfall for Kisumu is 1,430 mm.*

A distinctive feature is **asymmetric warming**—night-time temperatures are increasing faster than daytime ones, narrowing the diurnal range (Chang'a et al., 2017). The rising frequency of "warm nights" and heatwaves intensifies evapotranspiration, depletes soil moisture, and heightens risks to health, crops, and livestock. Warmer conditions also extend the range and survival of disease vectors such as malaria mosquitoes, and accelerate water stress even where rainfall totals remain unchanged.

Rainfall Variability

Rainfall behaviour in the basin is more complex than temperature trends. Overall, records indicate a modest wetting tendency of about 1–2 % per decade, but with large spatial and temporal variability (Kizza et al., 2009; Onyutha, 2021). The 1960s were exceptionally wet, while the 1980s–1990s experienced widespread drying (Figure 7-1; Table 7-1) (Nicholson, 2017).

Recent decades illustrate the **"East African Climate Paradox"**—declining long rains (March–May) but strengthening short rains (October–December) (Amanullah et al., 2020; Chang'a et al., 2017). Rainfall is increasingly concentrated into short, intense bursts separated by longer dry periods. Such changes disrupt planting calendars, raise flood and erosion risks, and reduce infiltration and groundwater recharge. While total rainfall may appear stable, its reliability has deteriorated, exposing communities to alternating flood and drought conditions.

Hydrological Extremes

Hydro-climatic extremes are intensifying. The basin now experiences one to two major flood or drought events each year, triple the rate recorded in the 1950s (FAO, 2004; Haile et al., 2022). The 2019–2020 floods, driven by intense OND and MAM rains, raised Lake Victoria to a new historic level surpassing the previous 1964 record, displacing hundreds of thousands across Kenya, Uganda, and Tanzania (Texbox 1). Within a year, the 2021–2022 drought struck, severely reducing agricultural production and water availability. Indices of very wet days (R95p) and dry-spell length both show upward trends, indicating a climate of more extreme oscillation—often termed "climate whiplash."

Textbox 7-1: Lake Victoria's Recent Flood Crises

The Lake Victoria Basin has endured two exceptional flood events within just four years—each revealing the growing volatility of the regional hydro-climatic system under a changing climate. Together, these floods illustrate the "climate whiplash" described in Chapter 7.1.1, where alternating extremes of drought and flood increasingly define the basin's environmental and socio-economic reality.

- **The 2019–2020 Floods:** Triggered by the strongest positive Indian Ocean Dipole in four decades, the basin experienced sustained, record-breaking rainfall beginning in late 2019. The extreme "short rains" of October–December 2019 saturated the catchment, and the subsequent "long rains" of March–May 2020 produced massive runoff, propelling Lake Victoria to a historic level of 13.42 m in May 2020—surpassing the previous 1964 record (Raballa, 2020; FEWS NET, 2020a). The event displaced more than 200,000 people across Kenya, Uganda, and Tanzania, submerging settlements, farmland, and fish-landing sites, and causing losses exceeding UGX 563 billion in Uganda alone (≈US$ 152 million) (Office of the Prime Minister, 2020). Scientific attribution studies confirmed that anthropogenic climate change increased both the probability and intensity of the event, while long-term environmental degradation—deforestation, wetland loss, and unplanned urbanization—greatly amplified its impacts (Pietroiusti et al., 2024; Khaki & Awange, 2021).
- **The 2023–2024 El Niño Floods:** The 2023–2024 El Niño floods reinforced the view that the 2019–2020 event was not an isolated anomaly but part of an emerging pattern of extreme hydrological variability. Following a prolonged drought, the combination of a strong El Niño and a positive IOD unleashed relentless rains, raising Lake Victoria's level to 13.77 m by May 2024—surpassing the previous record set in 2020 (WMO, 2023; UNDP, 2025). Riparian communities suffered widespread inundation, destruction of infrastructure, and severe public-health emergencies linked to cholera and malaria (OCHA, 2024; Center for Disaster Philanthropy, 2024).

Taken together, these back-to-back flood disasters confirm a new climate regime in which extreme rainfall and rapid hydrological swings are becoming more frequent and severe.

Spatial Patterns of Drought Risk

Drought vulnerability varies across the basin. The western and northeastern zones face recurring meteorological droughts linked to rainfall decline and high potential evapotranspiration, while the southern and eastern parts are more affected by agricultural drought due to soil-moisture deficits (Hao et al., 2022). The northwestern sub-basin shows the slowest drought recovery—often exceeding eight months—reflecting deep structural vulnerability (Nyeko-Ogiramoi et al., 2013). Targeted resilience investments—such as water-storage infrastructure, managed aquifer recharge, and climate-smart agriculture—are needed to address these localized stress patterns. Table 7-1 below summarizes the climate anomalies for the Lake Victoria Basin.

Other Emerging Climatic Indicators

Additional indicators confirm that climate change is reshaping the basin's physical systems in subtle but profound ways:

- **Evapotranspiration (PET):** Rising air temperatures have steadily increased PET across East Africa, intensifying water loss from soils and open water, reducing baseflows, and increasing irrigation demand (Onyutha, 2021).
- **Lake Surface Temperature (LST):** Lake Victoria's surface waters are warming by roughly 0.01 °C per year, reinforcing thermal stratification, reducing oxygen circulation, and promoting algal blooms that threaten fisheries productivity (Ahmed et al., 2018).
- **Wind and Convection Dynamics:** The land-lake breeze system, which drives nocturnal convection and thunderstorms, depends on temperature contrasts between land and water. Changing differentials appear to be altering wind intensity and timing, affecting rainfall distribution and increasing risks for night-time fishing (Benjamin et al., 2020; Bastiancich et al., 2022).

Table 7-1. Key Observed Climate Change Indicators in the Lake Victoria Basin (1950 – 2025). Baseline for anomalies is 1961–1990.

Period	Temperature Trend (°C / decade)	Precip. Trend (% / decade)	Temperature Anomaly (°C vs 1961-90)	Rainfall Anomaly (% vs 1961-90)	Frequency of Major Flood / Drought (per year)	Dominant Climate Features
1950 – 1969	~0.15 (early warming)	1	−0.1 to 0	±5	~0.3	Mostly stable climate; episodic wet years (1961–62)
1970 – 1989	~0.20	−2	0.2	−5 to −10	~0.5 – 0.8	Drying trend; onset of long-rain decline
1990 – 2009	~0.25	0	+0.4 – 0.7	Near normal	~1.0	Intensifying variability; frequent floods and droughts
2010 – 2025	~0.30	+1 to +2	+0.8 – 1.0	+2 – 5	1 – 2	Warmest period on record; heavier storms and longer dry spells
Overall (1950 – 2025)	+0.22 °C / decade	+1 – 2 % / decade	≈ +0.9 °C	No consistent long-term trend	≈ 3× higher than 1950s	Warming, intensified extremes, rising hydrological volatility

Sources: *Compiled from McSweeney et al. (2010); Kizza et al. (2009); Onyutha (2021); Nicholson (2017); Chang'a et al. (2017); Haile et al. (2022); World Bank (2021); WMO (2024, 2025).*

7.1.2 Future Climate Projections for the Basin

Future climate projections for the Lake Victoria Basin (LVB) are based on global and regional climate models that simulate the Earth's response to alternative greenhouse gas emission pathways. These scenarios—Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs)—provide a framework for understanding how global development choices will translate into regional climate outcomes, thereby guiding basin-wide adaptation and investment planning (IPCC, 2021).

Global Scenario Frameworks

The RCP–SSP system combines physical and socioeconomic dimensions of climate change. **RCPs** describe trajectories of radiative forcing, while **SSPs** depict alternative global futures that influence emissions through governance, technology, and inequality. Their integration produces "scenario families," such as **SSP1-2.6** (sustainable low-carbon development) and **SSP5-8.5** (fossil-fuel-intensive growth). The latter represents a high-emission future with radiative forcing exceeding 8 W/m² by 2100, while the former aligns with the Paris Agreement's ≤ 2 °C goal (Meinshausen et al., 2020).

For planners in the LVB, this framework links local risks directly to global policy choices. Figure 7-3 illustrates the projected divergence in atmospheric CO_2 trajectories across SSPs, underscoring that today's mitigation efforts will largely determine the region's climatic future.

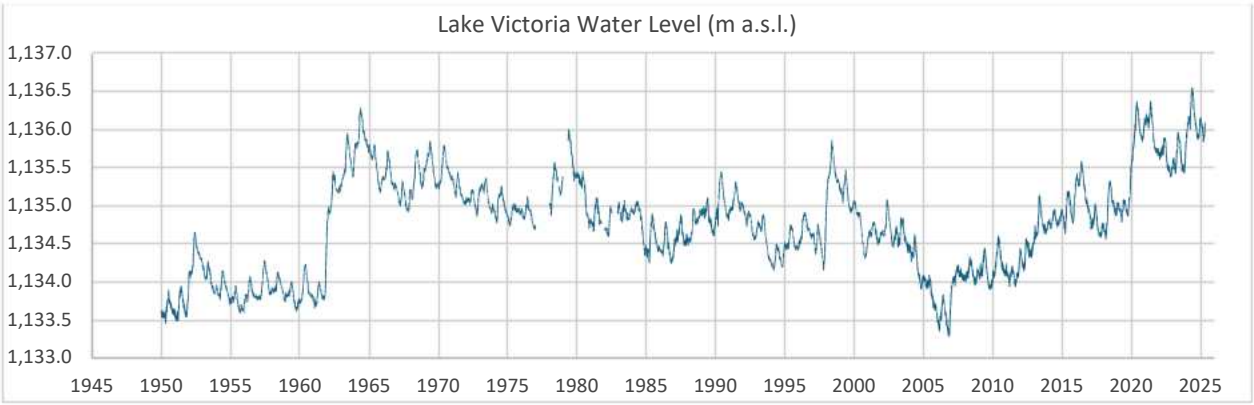


Figure 7-2. *Daily Lake Victoria Water Levels at Jinja Pier, Uganda (Source: Directorate of Water Resources Management, Ministry of Water and Environment, Uganda.*

The **Figure 7-2** above shows Lake Victoria's water levels to have varied considerably over the past eight decades, fluctuating within a range of approximately four meters. After reaching an early peak of 1,136m in the 1960s, levels remained relatively stable through the 1980s and 1990s before experiencing a sharp decline in the early 2000s. The lake reached its lowest recorded level around 2006 at approximately 1,133.3 meters above sea level. Since then, water levels have recovered dramatically, with the period from 2020 to 2025 showing the highest levels in the entire 80-year record, approaching 1,136.5 meters. This recent surge likely reflects increased rainfall patterns in the lake basin and ongoing climate variability in the region

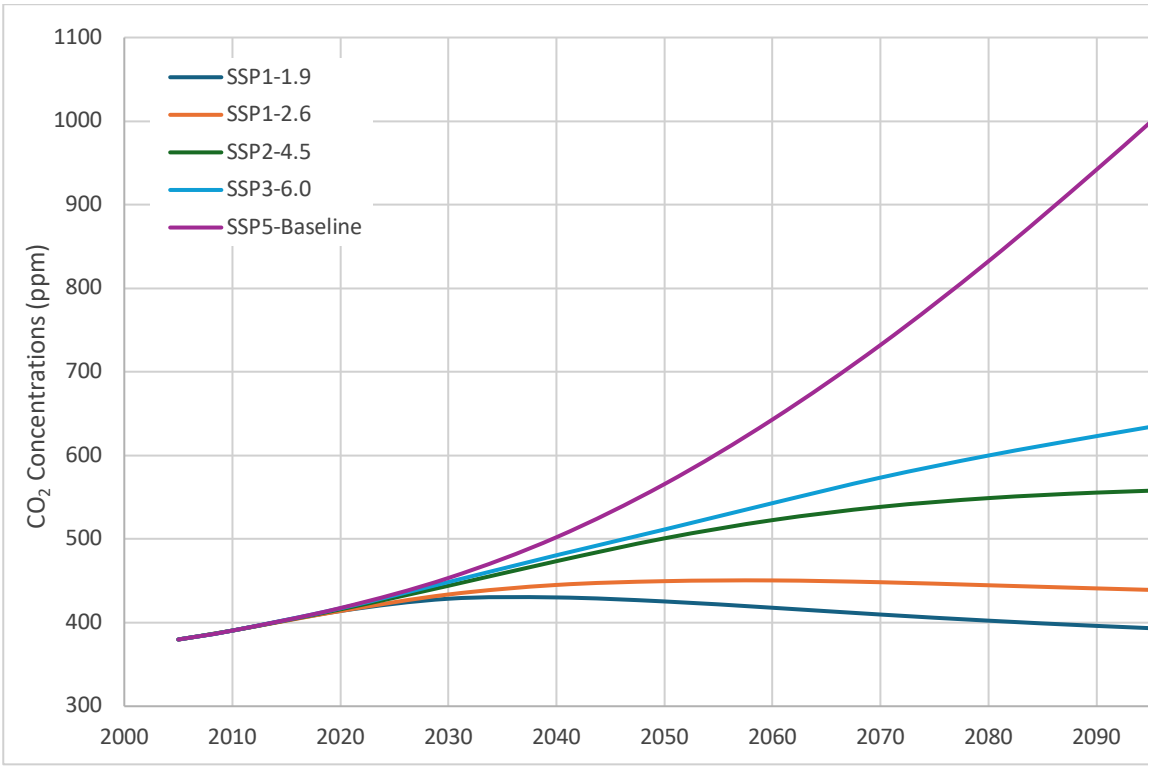


Figure 7-3. *Projected global trends in atmospheric CO2 concentrations under different SSP scenarios (Source: Meinshausen et al., 2020)*

Projected Temperature Trends

Across all model ensembles, a **substantial and accelerating rise in mean temperature** is projected across the LVB during the 21st century (Chang'a et al., 2017; Conway & Hulme, 1996). Warming is already detectable and is expected to intensify under every emissions pathway:

- **Near-term (2030s):** Average maximum temperatures may increase by 1.0–1.5 °C, and minimums by 1.2–1.9 °C above late-20th-century baselines.
- **Mid-century (2050s):** Under moderate mitigation (RCP4.5), warming of 1.6–2.0 °C (max) and 2.0–2.4 °C (min) is expected. Under high emissions (RCP8.5), these rise to 2.3–3.0 °C and 2.5–3.5 °C respectively.
- **End-century (2100):** Maximum temperatures could rise by up to 3.6 °C and minimums by 4.5 °C under the most pessimistic scenarios.

A consistent feature is **asymmetric warming**—night-time temperatures increasing faster than daytime ones—already evident in observed records (Section 7.1.1). This will heighten heat stress for humans, crops, and livestock, accelerate evapotranspiration, and reduce soil moisture. Seasonal patterns suggest greater warming during the **March–May (MAM)** and **June–September (JJAS)** periods, particularly in the north-western highlands and western shores (Figure 7-4). Such warming will shift crop calendars, shorten growing seasons, and increase cooling-water demand for hydropower plants.

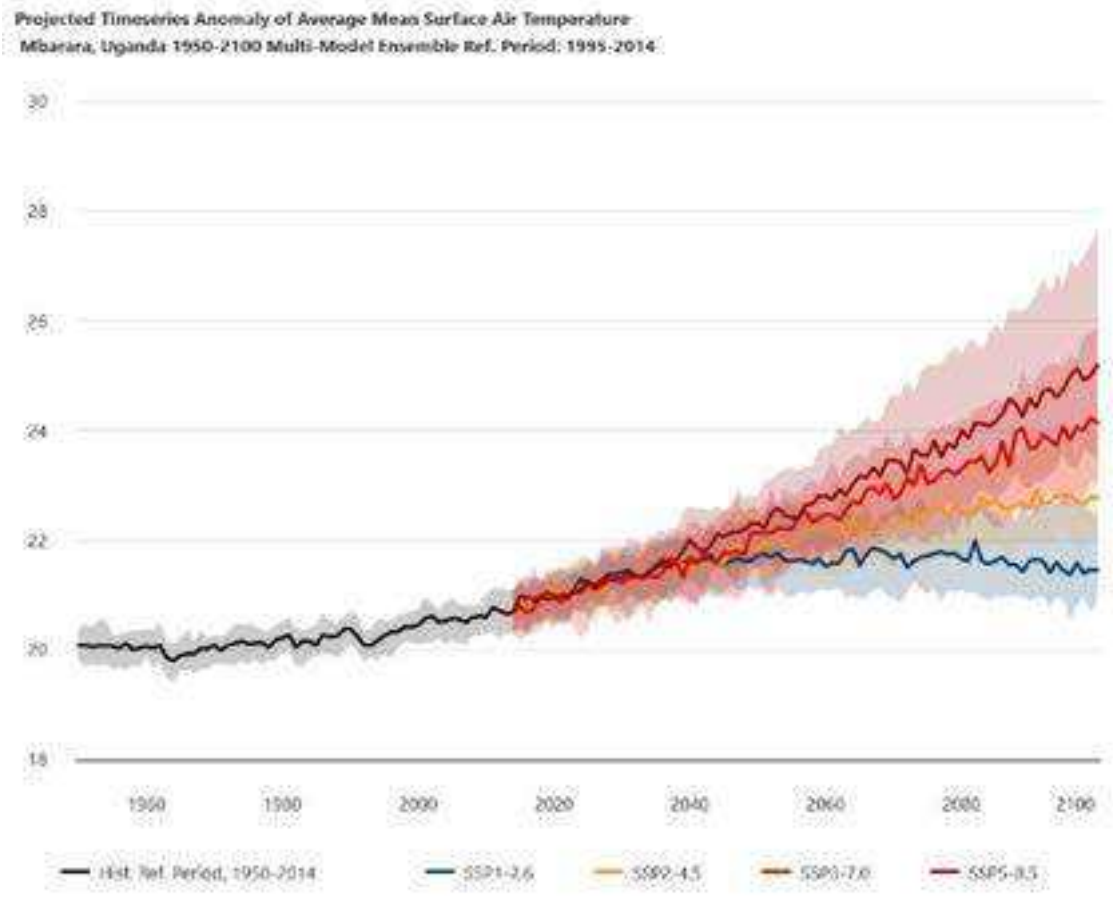


Figure 7-4. *Projected near surface temperature in Mbarara under different SSPs. Mbarara lies in the north-western part of the basin, which is an area projected to have increasing water stress. (Source: Word Bank Climate Change Portal).*

Projected Rainfall Patterns

While global warming tends to dry many sub-tropical regions, most climate models project a **long-term increase in mean annual rainfall** for the LVB—around 5 % by mid-century and 10–15 % by 2100 relative to the 1985–2014 baseline (Dunning et al., 2018). However, the aggregate increase masks **strong seasonal and spatial contrasts,** giving rise to what has been termed the ***East African Climate Paradox*** (Conway, 1993; Di Baldassarre et al., 2011).

- **October–December (OND) short rains:** Nearly all models simulate intensification, with rainfall increases of 15–25 % by mid-century, concentrated along the eastern and northern shores. This reflects enhanced westerly moisture inflow and stronger lake-land convection. Heavier OND rains imply higher flood, runoff, and erosion risks.
- **March–May (MAM) long rains:** Projections remain uncertain or show decline of up to 20–25 % in central and western areas through mid-century, followed by a modest rebound in some late-century models. This reinforces recent observations of delayed onset and early cessation of MAM rains, critical for agriculture.

Overall, the LVB is likely to become ***wetter on an annual basis*** but ***more unevenly so within the year***. This means more intense wet seasons

punctuated by prolonged dry spells—conditions that will complicate water-resource management and rain-fed farming.

Extremes and Hydrological Volatility

A warmer atmosphere can hold more water vapour, increasing the potential for **intense rainfall and hydrological extremes.** CMIP6-based analyses suggest the average precipitation intensity on wet days (SDII) could increase by ~16 %, while very heavy rainfall events (above the 99th percentile) may rise by ~40–50 % by late century (Dunning et al., 2018). The maximum 5-day rainfall total (RX5Day) is projected to grow by ~25–30 %.

Such intensification implies a future of more destructive downpours, especially during OND, interspersed with hotter and drier intervals. Figure 7-5 illustrates the observed trajectory toward this "hydrological whiplash," already manifested in the 2019–2020 and 2023–2024 flood events (see Text Box 7-1). Urban areas, floodplains, and deltas will face higher inundation risks, while extended dry seasons and droughts will stress ecosystems and water supply infrastructure.

Hydrological simulations for tributaries such as the Simiyu and Kagera Rivers show increasing frequency of both extreme discharge events and prolonged low-flow periods, highlighting the basin's exposure to **compound flood–drought hazards.**

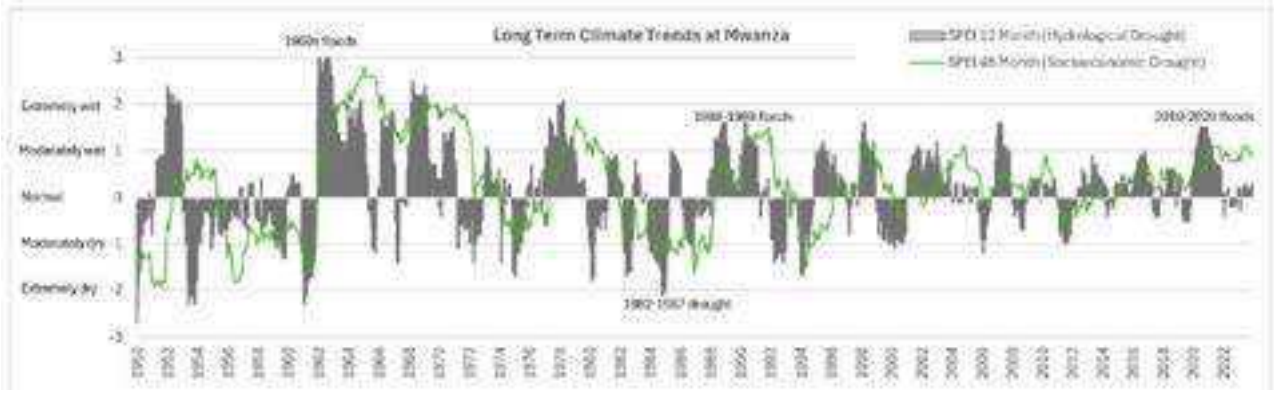


Figure 7-5. *Analysis of long-term climate trends in Mwanza (Source: Vicente-Serrano et al., 2010).*

Modeling Approaches and Uncertainties

Global Climate Models (GCMs) underpin these projections but operate at coarse spatial resolution (> 100 km grid), limiting their ability to capture the lake's mesoscale dynamics and strong diurnal cycles. To improve realism, outputs from CMIP5 and CMIP6 models are **downscaled**:

- **Statistical downscaling** refines GCM outputs using empirical relationships between large-scale circulation and observed local climate.
- **Dynamical downscaling** employs high-resolution Regional Climate Models (RCMs) nested within GCMs to simulate regional processes explicitly (Finney et al., 2020).

Because single-model results may be biased, **multi-model ensembles** corrected against observed records are preferred to characterize a range of plausible futures. Yet, uncertainty remains significant—particularly for seasonal rainfall—due to:

1. **Model representation of convection,** which strongly affects tropical rainfall intensity and timing;
2. **The East African paradox**, where observed drying of MAM rains contrasts with some modelled wetting trends; and
3. **Uncertain behaviour of oceanic drivers** such as the Indian Ocean Dipole (IOD) and El Niño–Southern Oscillation (ENSO), which influence moisture transport into the basin.

Implications for Planning

Despite uncertainty in rainfall magnitude and distribution, there is strong consensus on the direction of change: the **basin will become significantly warmer,** the **OND short rains will intensify, and extreme events will grow more frequent and damaging**. For basin planners, these projections define ***risk envelopes*** rather than precise forecasts. Building resilience therefore calls for flexible, no-regret strategies—expanding multipurpose water storage, investing in **blended grey and green infrastructure** that integrates engineered and nature-based systems, promoting climate-smart agriculture, and strengthening flood and drought management frameworks. Furthermore, integrating climate information into basin-wide planning and linking local adaptation with global mitigation objectives remain essential to moderating long-term risks and sustaining the Basin's socio-ecological balance.



Figure 3-1. A surfer at Serena Beach, Mombasa. Climatic processes over the Indian Ocean have a huge influence on the climate of eastern and southern Africa. (Source: baecation.co.ke)

7.2: Vulnerability to Climate Change

This section analyzes the Lake Victoria Basin's (LVB) high vulnerability to climate change, where exposure to floods, droughts, and storms intersects with poverty, fragile ecosystems, and limited adaptive capacity. It begins with a **vulnerability assessment** (Section 7.2.1) that identifies geographic and livelihood hotspots—showing how rain-fed agriculture, fisheries, and pastoralism are increasingly at risk—and highlights the differentiated impacts on women, youth, and marginalized groups. It then examines **climate-induced migration** (Section 7.2.2), explaining how declining land and water productivity are reshaping population movements across the Basin. Together, these analyses show that vulnerability in the LVB is systemic, demanding coordinated adaptation that integrates climate resilience with social and economic transformation.

7.2.1 Vulnerability Assessment

Climate Vulnerability of the Lake Victoria Basin

The Lake Victoria Basin (LVB) is among Africa's most climate-vulnerable regions. Its economy and livelihoods depend heavily on rain-fed agriculture, pastoralism, and inland fisheries, all of which are highly sensitive to temperature and rainfall variability (World Bank, 2025a; NBI, 2018). The lake's water balance is dominated by direct rainfall and evaporation, making its hydrology acutely responsive to climatic fluctuations (Awange & Ogalo, 2006). Increasingly frequent floods, droughts, and storms magnify socio-economic and ecological stresses, particularly where high exposure coincides with fragile livelihoods and degraded ecosystems (Philip et al., 2024).

Geographic and Hydro-Climatic Hotspots

Vulnerability varies across the basin. Flood-prone lowlands such as the Yala Swamp, Mara Basin, and Nzoia and Kagera floodplains face recurrent inundation; the 2019–2020 floods displaced thousands and damaged infrastructure. Semi-arid zones of Kenya and Tanzania suffer from recurrent droughts and pasture loss, while steep catchments in Rwanda and Burundi experience landslides triggered by intense rainfall and deforestation (Said et al., 2023). Lakeshore and island communities face shoreline flooding and violent nocturnal storms that cause hundreds of fishing fatalities annually (del Moral Méndez et al., 2025). Rapidly expanding urban centers—Kisumu, Mwanza, Homa Bay—suffer flash floods, poor drainage, and disease outbreaks, reflecting intertwined climatic and governance vulnerabilities (Global Center on Adaptation, 2025).



Climate-Sensitive Livelihoods

Climate extremes directly undermine the basin's key livelihood systems. Rain-fed smallholder agriculture, which employs up to 80 percent of the population, faces erratic rainfall, prolonged dry spells, and storm damage that reduce yields and deepen food insecurity (Were et al., 2020). Fisheries—supporting over 3 million people and generating about US$1.1 billion annually—are affected by rising water temperatures, reduced oxygen levels, and storm hazards that endanger fisherfolk and damage equipment (Aura et al., 2022). As drought drives more people into fishing, overexploitation and conflicts increase, revealing systemic interlinkages between sectors.

Poverty and Adaptive Capacity Gaps

Widespread poverty and service deficits amplify vulnerability. Many households subsist below US$1.25 per day and lack access to irrigation, insurance, and early-warning systems (Marcus & Wu, 2023). Coping strategies such as deforestation or child labor offer short-term relief but erode long-term resilience, reinforcing a poverty–environment trap (Yongo et al., 2022). Weak infrastructure and limited access to clean water and sanitation heighten disaster impacts and disease risks (WMO, 2023).

Differential Vulnerabilities

Climate impacts are unevenly distributed.

- **Women** bear disproportionate burdens due to gendered roles, insecure land tenure, and restricted access to credit and technology. Post-harvest fish losses and increased water-collection burdens reduce their income and time for other pursuits (Adam, 2024; Stockholm Environment Institute, 2021).
- **Youth**, who constitute the basin's majority, face disrupted education, declining rural opportunities, and growing climate anxiety (OCHA, 2024; Carnegie Endowment, 2025). Yet their innovation and digital connectedness make them critical actors in adaptation.
- **Indigenous and local communities** are highly exposed to ecosystem degradation but hold valuable Indigenous and Local Knowledge (ILK) that can enhance locally grounded adaptation if integrated with scientific forecasting (Marcus & Wu, 2023).

7.2.2 Climate-Induced Migration

Rising Climate Stress and Human Mobility in the Basin

The Lake Victoria Basin (LVB) is rapidly emerging as one of Africa's foremost hotspots of climate-induced human mobility. Historically, population movement in the basin was driven by trade, pastoralism, and livelihood diversification; today, environmental degradation and climate variability have become structural drivers of migration. Increasingly erratic rainfall, recurrent floods and droughts, and declining land and water productivity are displacing households and reshaping settlement patterns across Burundi, Kenya, Rwanda, Tanzania, and Uganda (World Bank, 2021; Rigaud et al., 2021). The convergence of demographic pressure, fragile ecosystems, and climate stress is transforming migration from a coping strategy into a defining feature of the basin's socio-economic landscape.

The Climate–Migration Nexus

Climate change influences mobility primarily through its impacts on water, food, and livelihood security. The *Groundswell Africa* analysis identifies water availability as the most potent climate variable determining migration decisions within the basin. Declining rainfall reliability, rising evapotranspiration, and soil degradation have undermined agricultural productivity—especially among rainfed smallholders who constitute the majority of the population. In response, households adopt a spectrum of adaptive strategies, from short-term seasonal movement to permanent relocation to urban or peri-urban areas offering alternative livelihoods.

Areas with relatively stable rainfall and fertile soils—particularly the Lake Victoria shoreline, central Rwanda, and parts of Tanzania and Uganda—are projected to become **in-migration hotspots**, attracting climate migrants seeking livelihood security. Conversely, semi-arid zones in northern Uganda, eastern and southern Tanzania, and degraded highland catchments are expected to experience **out-migration**, driven by water scarcity, crop failure, and ecosystem collapse (Rigaud et al., 2021). This spatial reconfiguration of human settlements underscores the direct linkage between hydrological change, land degradation, and population mobility in the basin.

Projected Scale and Patterns

Projections indicate that without strong climate and development action, up to **38.5 million people**—approximately **10% of the projected population** of the five basin countries—could become internal climate migrants by 2050 under a high-emissions, unequal-development scenario (World Bank, 2021). Tanzania and Uganda could each host over 12–16 million climate migrants, while Kenya, Rwanda, and Burundi together may account for another 10 million. Under an inclusive, low-emissions pathway, these numbers could decline by about 30%, demonstrating the power of early action to mitigate displacement.

Migration is expected to accelerate from the 2030s onward, with climate-related mobility potentially outpacing non-climate internal migration by mid-century. The basin's lakeshore zones, mid-altitude agricultural areas, and rapidly growing urban centers—Kampala, Kisumu, Mwanza, and Kigali—are projected to absorb much of this population, intensifying already high settlement densities and infrastructure pressures. In contrast, coastal cities like Mombasa and Dar es Salaam face climate out-migration due to sea-level rise and storm surge risks. The overall trajectory points toward a widening imbalance between population concentration and the carrying capacity of local ecosystems.

Socio-Economic and Governance Implications

Climate-induced migration is both a symptom of vulnerability and an adaptive response. Managed well, it can redistribute population away from high-risk zones and diversify household income sources; unmanaged, it can amplify environmental degradation, social tension, and poverty. In-migration to lakeshore and urban areas is already heightening demand for water, sanitation, housing, and land, while expanding informal settlements in flood-prone zones. These pressures compound existing governance challenges, as municipalities and basin authorities struggle to provide services and enforce land-use regulations.

Moreover, migration interacts with other stressors—youth unemployment, gender inequality, and cross-border movements—to produce multidimensional risks. Women and children are disproportionately affected, often facing reduced access to education, healthcare, and secure livelihoods in displacement contexts. The situation calls for a shift from reactive humanitarian approaches to proactive, development-oriented adaptation strategies that integrate mobility into basin planning and national development frameworks.

Policy Pathways and Adaptive Opportunities

The *Groundswell Africa* report proposes a comprehensive **Migration and Climate-informed Solutions (MACS)** framework that is highly relevant for the Lake Victoria Basin. Building on this, key policy directions for the region include:

1. **Integrate migration into basin planning and national development strategies,** ensuring that LVBC's Integrated Water Resources Management and Development (IWRMD) Strategy (2023–2050) explicitly accounts for population mobility trends.
2. **Invest in climate-resilient livelihoods** in out-migration areas—such as drought-tolerant crops, sustainable pastoralism, and land restoration—to reduce distress displacement.
3. **Plan for inclusive and resilient urban growth**

in in-migration hotspots, emphasizing green infrastructure, housing, and wastewater management.

4. **Harness migration as an adaptation pathway**, by promoting safe labor mobility, remittance-based investment in climate-smart enterprises, and skills development for displaced populations.
5. **Strengthen data, early warning, and coordination systems** to anticipate migration flows and align humanitarian, development, and peacebuilding interventions.

Embedding these measures within regional cooperation frameworks under the East African Community will be essential to transform migration from a crisis response into an adaptive mechanism that strengthens basin-wide resilience.

This section provides a comprehensive, evidence-based assessment of the multifaceted and interconnected impacts of climate change across the Lake Victoria Basin. It examines the cascading effects of rising temperatures and altered hydro-climatic regimes on the basin's water resources, its unique ecosystems and biodiversity, its key economic sectors, and ultimately, the health and well-being of its human population.

7.3 Impacts of Climate Change

This section analyzes how climate change is reshaping the Lake Victoria Basin's (LVB) natural systems, economies, and livelihoods. It begins with **impacts on water resources and hydrology** (Section 7.3.1), highlighting how rising temperatures, erratic rainfall, and extreme events are disrupting river flows, lake levels, and water quality. It then examines **ecosystem and biodiversity impacts** (Section 7.3.2), showing how warming, habitat loss, and invasive species are degrading aquatic and terrestrial environments. The section also assesses **human health and economic losses** (Sections 7.3.4–7.3.5), linking climate extremes to disease outbreaks, food insecurity, and infrastructure damage. It concludes with a **synthesis** (Section 7.3.6), emphasizing that these cascading impacts are interdependent and call for coordinated, transformative adaptation across the Basin.

7.3.1 Impacts on Water Resources and Hydrology

Climate change is profoundly altering the hydrological dynamics of the Lake Victoria Basin (LVB). Rising temperatures and increasingly erratic rainfall patterns are reshaping the timing, magnitude, and spatial distribution of water flows. These shifts are not linear but represent a systemic destabilization of the water cycle on which the basin's ecosystems, economies, and over 45 million people depend.

More Intense Floods and Droughts

The basin's climate is becoming both wetter and more volatile, with an intensification of extreme events at both ends of the spectrum. Climate projections indicate a 20–30% increase in the frequency and intensity of heavy rainfall events toward the end of the century (ICPAC, 2023). The catastrophic 2019–2020 floods, which displaced over 200,000 people and submerged wide stretches of shoreline infrastructure, exemplify this pattern. The subsequent 2023–2024 El Niño floods reinforced that these are no longer isolated anomalies but part of a recurring pattern of hydro-climatic extremes (see Text Box 7-1).

Conversely, the "long rains" (March–May) on which agriculture depends have become shorter and less reliable, while dry spells lengthen. This "hydrological whiplash" exposes communities to alternating floods and droughts, crippling traditional farming systems, stressing urban water supply networks, and overwhelming infrastructure designed for a more stable climate. Figure 7-6 illustrates the scale and human impacts of extreme hydrological events across the Lake Victoria Basin over the past 25 years.

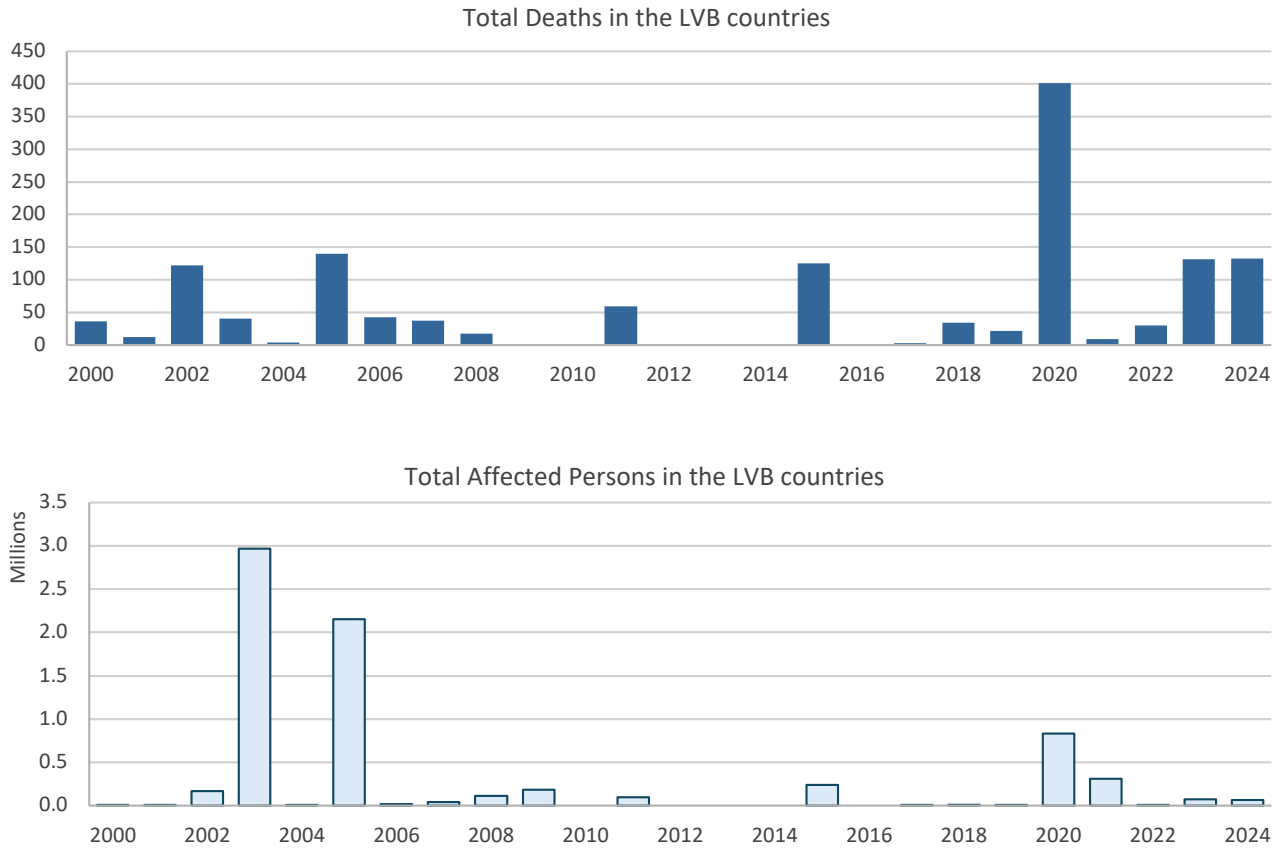


Figure 7-6. *Total deaths and total affected persons from floods, droughts, storms and landslides in the Lake Victoria Basin (source: EM-DAT, 2025).*

Rising Evapotranspiration and Crop Water Stress

Higher air temperatures are intensifying evapotranspiration from Lake Victoria's vast surface, wetlands, soils, and vegetation, accelerating the loss of water to the atmosphere (Awange & Ogalo, 2006). This is a dominant component of the lake's water balance, often equalling the amount received from direct rainfall. The resulting rise in Potential Evapotranspiration (PET) increases atmospheric demand for water, causing faster drying of landscapes and reduced soil moisture.

Critically, this temperature-driven increase in evaporative losses may partially or fully offset the projected wetting trend, effectively cancelling out gains from increased rainfall. As a result, seasonal and inter-annual water shortages may intensify even under a general long-term wetting scenario, particularly during dry seasons and drought years.

For agriculture—on which most of the basin's population depends—this translates into markedly higher crop water requirements. Rain-fed crops face increasing deficits between water demand and available rainfall, forcing greater reliance on irrigation (Kashaigili et al., 2023). This in turn heightens competition for limited surface and groundwater supplies and exposes the basin's fragile aquifers to over-abstraction risks.

Changing River Flow Regimes

Observed discharge records show significant hydrological responses to climatic and land-use changes. Rivers such as the Mara and Simiyu exhibit upward flow trends linked to increased rainfall (Cambula, 1999), while others display rising peak discharges even when annual rainfall remains constant (Conway, 2002). These shifts indicate intensified runoff and flashier hydrological responses associated with degraded catchments.

Future projections remain spatially diverse. Catchments like Katonga and Nyando may experience higher flows as extreme rainfall offsets evaporation losses, whereas the Simiyu catchment could see up to a 30% decline in mean annual discharge by 2060 due to higher evapotranspiration and reduced rainfall (Al-Ansari et al., 2014). Despite this heterogeneity, models consistently agree on greater variability and more frequent extreme flows, requiring a shift from managing for averages to planning for volatility. Spatial analyses of projected flow variability (Figures 7-7 and 7-8) reveal more hydrologically stable western catchments such as Kagera and Katonga, contrasted with highly "flashy" southern and eastern systems, including Nyando, Mara, and Mbalageti.

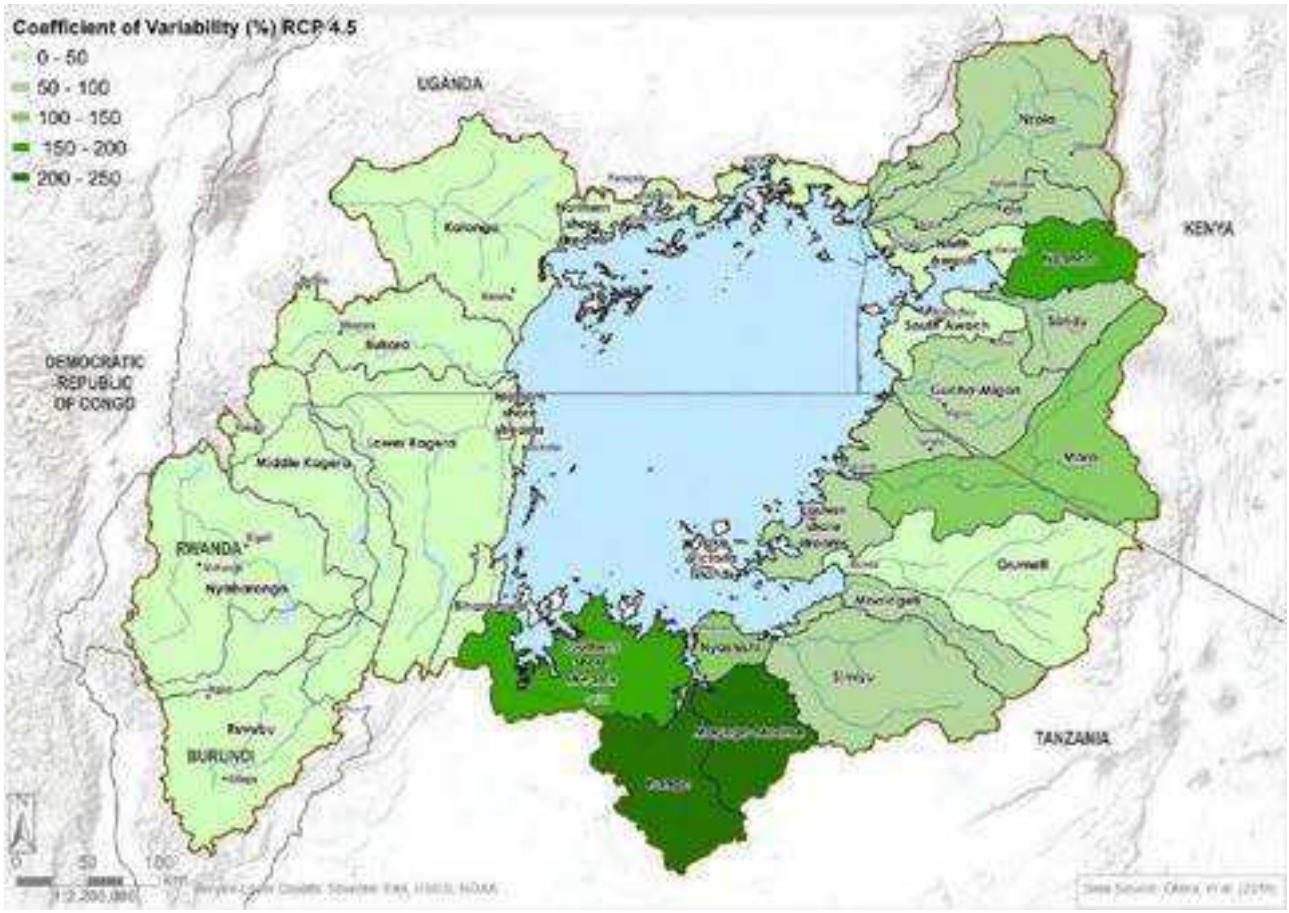


Figure 7-7. *Coefficient of Variation (CoV) % for the period of 2030-2050 for medium emissions scenario*

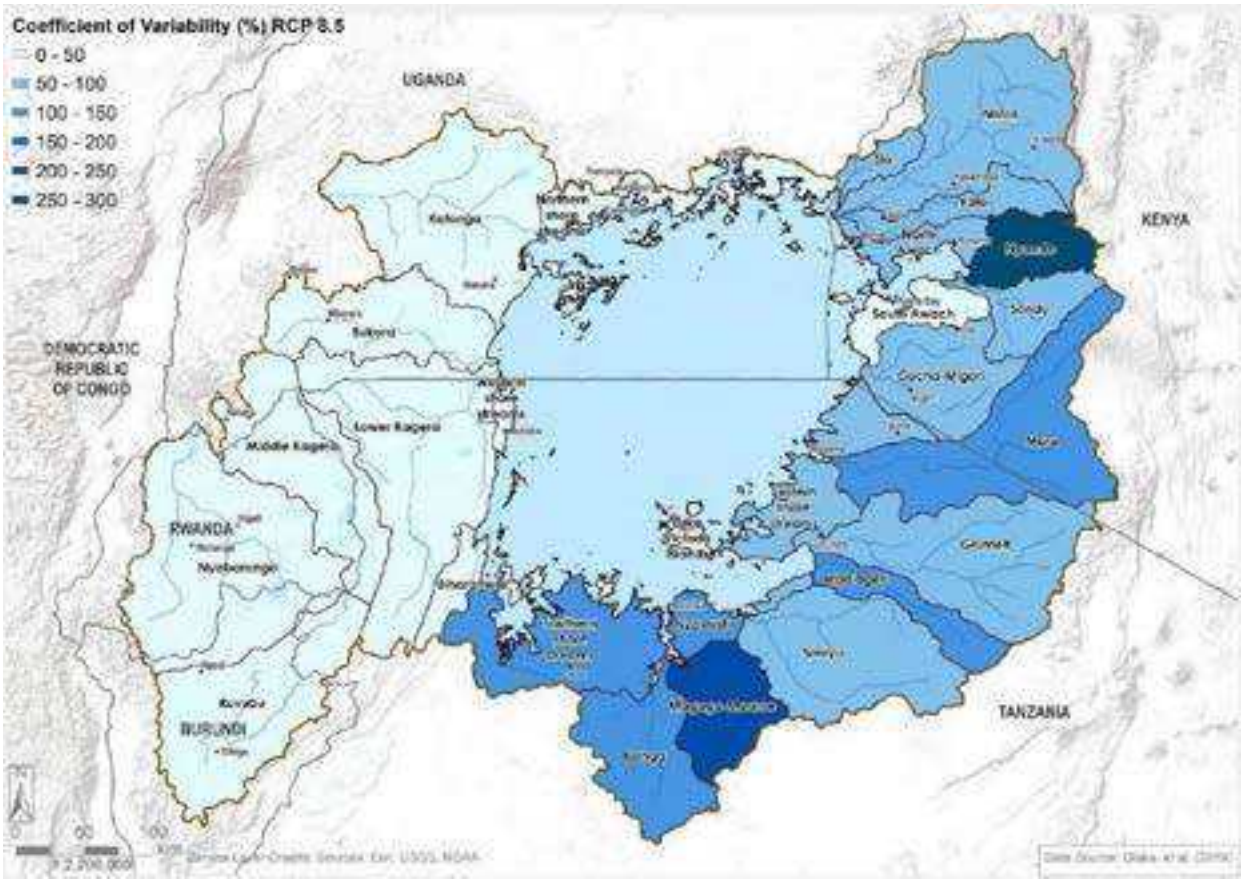


Figure 7-8. *Coefficient of Variation (CoV) % for the period of 2030-2050 for a high emissions scenario*

Lake Levels and Groundwater Recharge

Lake Victoria's water level—controlled mainly by the balance between rainfall and evaporation—is highly sensitive to climatic perturbations. Some models anticipate declining levels as evaporation outpaces rainfall, threatening navigation, hydropower generation, and water supply. However, the sharp 1.44-m rise recorded between 2019 and 2020, which surpassed the 1964 historical peak, shows how extreme precipitation can rapidly drive levels upward (Clement et al., 2024). Both extremes—declining and excessive levels—pose serious risks to riparian settlements and infrastructure.

Groundwater dynamics exhibit similarly mixed responses. Increased rainfall may enhance recharge in some areas; a study in Uganda, for instance, projected a 13–15% rise in recharge under wetter scenarios (IWA Publishing, 2024). Yet, deforestation and wetland conversion are undermining infiltration capacity, increasing surface runoff, and limiting aquifer replenishment. The transboundary Kagera aquifer—already characterized by low natural recharge—is particularly vulnerable (GIZ, 2025).

Erosion, Sedimentation, and Water Quality

Intensifying rainfall over degraded hillslopes has accelerated soil erosion and sediment transport, compounding long-standing land degradation (World Bank, 2022). Sediment-laden runoff reduces water storage capacity, clogs waterways, and raises flood risk downstream. At the lake scale, this inflow of sediments and nutrients fuels eutrophication, algal blooms, and oxygen depletion. Warming water and stronger thermal stratification exacerbate these effects by limiting vertical mixing and oxygen renewal in deeper layers (Frontiers, 2024a). The cumulative result is declining water quality, expanding hypoxic zones, and habitat loss for fisheries and biodiversity.

7.3.2 Impacts on Ecosystems and Biodiversity

Climate change is transforming the ecological balance of the Lake Victoria Basin, disrupting both aquatic and terrestrial systems and endangering the biodiversity that supports livelihoods and ecosystem services.

Aquatic Ecosystems

Rising lake surface temperatures and intensified thermal stratification are expanding low-oxygen deep zones, confining fish and other aerobic organisms to shallow waters. This "habitat squeeze" favors heat- and hypoxia-tolerant species while disadvantaging endemic, cold-water taxa such as many cichlids (IPCC, 2022; World Bank, 2025). Combined with long-standing pressures from the Nile Perch introduction, these stressors simplify food webs, weaken resilience, and threaten the basin's fisheries—a major source of food and income.

Terrestrial Ecosystems

On land, climate stress interacts with land-use change to accelerate biodiversity loss. Forest cover has fallen sharply since the early 20th century, largely due to agricultural expansion, wood extraction, and settlement (MDPI, 2024). Shifts in temperature and rainfall regimes are altering habitat suitability, yet fragmented landscapes limit species' ability to migrate or adapt, increasing extinction risks (Frontiers, 2025).

Wetlands and Forests

Wetlands, vital for flood buffering and water purification, face dual threats from encroachment and climatic extremes. Record floods in 2020 inundated many littoral wetlands, while intensifying droughts now threaten their desiccation (Copernicus Publications, 2023; World Bank, 2025). Forest degradation—driven by charcoal demand and declining agricultural productivity—further erodes soil stability and watershed regulation, amplifying runoff and sedimentation (University of Alberta, 2022). These dynamics reinforce a vicious cycle of ecosystem decline and human vulnerability.

Invasive Species

Warming and eutrophication promote invasive proliferation, notably of water hyacinth (***Eichhornia crassipes***), which forms dense mats that block sunlight, deplete oxygen, and disrupt fisheries and navigation (Minha et al., 2024). Flood-driven dispersal events, such as those following the 2006 and 2020 floods, underscore how climate extremes and invasives interact to magnify ecological and economic losses (NASA Earth Observatory, 2007).

7.3.4 Impacts on Human Health and Well-Being

Climate change is increasingly undermining public health and human security in the Lake Victoria Basin (LVB). Rising temperatures, erratic rainfall, and extreme events are intensifying disease burdens, food and nutrition insecurity, heat stress, and forced migration—posing systemic risks to human development across the region.



Disease Burden and Public Health Risks

Climate variability is reshaping disease ecology. Floods overwhelm sanitation systems and contaminate drinking water, driving recurrent outbreaks of cholera, typhoid, and other diarrhoeal diseases. Historical El Niño events have coincided with major cholera epidemics, demonstrating the climate–disease nexus. Simultaneously, warming temperatures are extending the range and seasonality of malaria transmission into highland zones previously too cool for mosquito survival, exposing new, vulnerable populations (IPCC, 2022; WMO, 2023).

Nutrition, Food Security, and Heat Stress

Declining crop and fisheries yields—driven by droughts, floods, and thermal stress—are reducing food availability and dietary diversity, particularly among children and low-income households. Malnutrition weakens immunity and heightens susceptibility to infection, reinforcing a vicious cycle of ill-health and poverty. Rising temperatures also expose outdoor workers, the elderly, and children to heat stress, reducing labour productivity and household income (IPCC, 2022).

Climate-Induced Displacement and Well-Being

Extreme floods and droughts increasingly trigger population movements. The 2019–2020 and 2023–2024 flood events displaced tens of thousands in Kenya, Tanzania, and Uganda, demonstrating the human toll of intensifying climatic extremes. Looking ahead, the *Groundswell Africa* analysis projects that up to 38.5 million people in LVB countries could become internal climate migrants by 2050 under high-emission scenarios—most in Tanzania and Uganda (World Bank, 2021a,b). Such migration from degraded rural areas to urban centers will strain housing, infrastructure, and social services, deepening poverty and heightening risks of social tension (World Bank, 2025b).

The Table 7-2 below provides a synthesis of climate-related impacts and vulnerabilities across key sectors of the LVB.

Table 7-2. Sector-Specific Climate Change Impacts and Vulnerabilities in the Lake Victoria Basin

Economic/Social Sector	Key Climate Drivers	Observed & Projected Impacts	Key Sources
Water Resources	Increased rainfall intensity; rising temperatures; drought	Altered lake levels, "flashier" river flows, degraded water quality, stress on groundwater.	(UNFCCC, n.d.; Copernicus Publications, 2023; Awange & Ogalo, 2006)
Ecosystems	Rising water temp; extreme events; nutrient loading	Anoxic zones, habitat loss (wetlands, forests), biodiversity loss, proliferation of invasive species.	(UNFCCC, n.d.; World Bank, 2025b; ResearchGate, 2015b)
Agriculture	Rainfall unpredictability; drought; floods	Disrupted planting seasons, crop failure, soil erosion, reduced yields.	(FAO, n.d.; IWA Publishing, 2023a; NCBI, 2014)
Livestock	Drought; heat stress	Water and pasture scarcity, increased disease outbreaks, livestock mortality.	(ResearchGate, 2015a; Frontiers, 2025a)
Fisheries	Warming waters; anoxia; extreme weather	Reduced productivity, habitat squeeze, frequent mass fish kills.	(EBSCO, n.d.; ResearchGate, 2013; Mongabay, 2023)
Hydropower	Extreme variability in lake levels/flows	Unreliable power generation, infrastructure stress.	(Thiery et al., 2018; Adaptation Fund, 2017)

Economic/Social Sector	Key Climate Drivers	Observed & Projected Impacts	Key Sources
Infrastructure	Floods; landslides	Damage to roads, bridges, ports, buildings, disrupting transport and trade.	(Copernicus Publications, 2023; World Weather Attribution, 2024)
WASH	Flooding; drought	Contamination of water sources, damage to sanitation facilities, water scarcity.	(Adaptation Fund, 2016; IWA Publishing, 2023a; Marcus, 2022)
Human Health	Rising temps; floods	Increased malaria, cholera; malnutrition; heat stress.	(IPCC, 2022; PubMed, 2007)
Human Well-being	Cumulative impacts on all sectors	Large-scale internal migration, increased poverty and conflict risk.	(World Bank, 2021a; World Bank, 2021b)

7.3.5 Direct Economic Loss from Disasters

Climate-related disasters continue to inflict heavy economic losses across the Lake Victoria Basin, undermining development gains and highlighting growing climate vulnerability. Sustainable Development Goal Indicator 11.5.2 measures such direct economic losses relative to national GDP, capturing damages to infrastructure, agriculture, productive assets, and housing.

As shown in **Table 7-3**, the Basin's Partner States experienced significant losses between 2020 and 2024. Kenya recorded the highest absolute losses—about USD 1.85 billion—mainly from the 2022–2023 drought and recurrent flooding. Burundi and Rwanda, however, suffered the greatest losses relative to GDP, underscoring their high exposure and limited adaptive capacity.

Table 7-3. Direct Economic Loss from Disasters in Lake Victoria Basin Countries (2020-2024) (source: EAC Germany, 2025; Copernicus Publications, 2024).

Country	Economic Loss (USD millions)	Percentage of GDP	Most Affected Sectors	Major Loss Events
Kenya	1,850	1.8%	Agriculture, transportation, housing	2020 floods: $390m loss; 2022-2023 drought: $1.2b loss
Uganda	920	2.1%	Agriculture, energy, tourism	2020 shoreline flooding: $220m loss; 2021 landslides: $180m loss
Tanzania	1,260	1.6%	Agriculture, transportation, water supply	2020 river floods: $310m loss; 2023 drought: $750m loss
Rwanda	480	2.4%	Agriculture, infrastructure, housing	2020 landslides: $120m loss; 2023 floods: $240m loss
Burundi	380	3.2%	Agriculture, housing, health	2021 floods: $190m loss; 2023 drought: $150m loss

Agriculture remains the most affected sector, accounting for roughly 50–70 percent of total losses due to dependence on rain-fed production and weak irrigation infrastructure. The prolonged 2022–2023 drought alone caused losses exceeding USD 2 billion across the five countries, pushing an estimated 12 million people into acute food insecurity. Infrastructure damages were also severe: floods and landslides destroyed roads, bridges, and utilities—such as the USD 200 million in road damage in Tanzania during 2020 and the extensive flood-related infrastructure losses in Rwanda in 2023.

These impacts illustrate how extreme events translate into cascading economic disruptions—through reduced market access, supply-chain breakdowns, and constrained emergency responses. They also expose systemic weaknesses in climate-resilient planning and infrastructure design, emphasizing the urgency of integrating disaster-risk reduction and adaptive investment planning into basin-wide development strategies (EAC Germany, 2025; Copernicus Publications, 2024).

7.3.6 Summary: A Basin Under Siege

Interconnected Climate Impacts

Climate change is already reshaping the Lake Victoria Basin, triggering a web of interlinked disruptions across water systems, ecosystems, economies, and societies. A destabilized hydrological cycle—marked by rising temperatures, heightened evapotranspiration, and erratic rainfall—has created a new pattern of extremes. Floods and droughts now occur in rapid succession, degrading soils, increasing sediment and nutrient inflows, and reducing water quality. The 2019–2020 floods, which displaced over 200,000 people and raised lake levels to record highs, illustrate the growing volatility of the basin's climate (Pietroiusti et al., 2024; WMO, 2025).

Ecosystem and Economic Disruptions

Aquatic and terrestrial ecosystems are under severe stress. Rising lake temperatures and prolonged stratification expand oxygen-depleted zones, threatening endemic fish species and the viability of Africa's largest inland fishery. On land, degraded habitats and invasive species such as water hyacinth proliferate under warming conditions. These ecological shifts reverberate through key economic sectors—rain-fed agriculture, hydropower, and transport infrastructure—all increasingly vulnerable to climatic extremes. Annual economic losses from floods and landslides are mounting across basin countries (see Table 7-3).

Human Well-being and the Need for Transformation

The human toll is profound. Climate change undermines food and water security, heightens disease outbreaks, and fuels displacement that could affect up to 38 million people by 2050 (World Bank, 2024). Building resilience will therefore require transformative and cooperative action—protecting wetlands and forests, adapting agriculture and infrastructure to variable conditions, and strengthening regional coordination in managing shared resources and risks.

The next section outlines the adaptation strategies and transformative measures essential to safeguard the basin's future.

7.4 The Enabling Framework: Policy, Governance, and Finance

This chapter examines the enabling framework for climate action in the Lake Victoria Basin, emphasizing that effective responses require strong institutional and financial foundations alongside technical solutions. It focuses on three interlinked pillars: policy and legislation, which set the strategic direction; governance and institutions, which ensure coordination and implementation; and finance, which mobilizes resources to turn commitments into results. The sub-chapter moves from regional to national contexts, reviewing cooperative mechanisms, institutional landscapes, and the evolving climate finance ecosystem, and concludes with recommendations to strengthen the basin's collective capacity for climate-resilient development.

7.4.1 Regional Policy and Cooperation Frameworks

Managing the Lake Victoria Basin's shared resources demands strong regional cooperation. Within the East African Community (EAC), partner states have established coordinated policy and institutional frameworks to address climate change collectively.

EAC Climate Policy Framework

The EAC Climate Change Policy provides the overarching framework for regional action, aiming to harmonize measures that strengthen climate resilience and sustainable development, particularly through adaptation (EAC, 2011). It is operationalized by the EAC Climate Change Strategy and guided by the Climate Change Master Plan (2011–2031), which envisions climate-resilient economies and ecosystems. However, the partial ratification of the Protocol on Environment and Natural Resources Management continues to limit the enforceability of these regional commitments.

Institutional Arrangements and Transboundary Action

The Lake Victoria Basin Commission (LVBC) serves as the regional hub for coordinating climate-related initiatives. It harmonizes policy, implements basin-wide adaptation projects, and facilitates joint resource mobilization. Flagship initiatives—such as the Adaptation Fund–financed ***Adapting to Climate Change in the Lake Victoria Basin (ACC-LVB)*** and the ***Nile Cooperation for Climate Resilience (NCCR)***—demonstrate the Basin's capacity for cross-border ecosystem-based adaptation and climate information services (Adaptation Fund, 2017; UNEP, 2024). Complementary institutions reinforce this effort: the Lake Victoria Fisheries Organization (LVFO) supports sustainable fisheries management, the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) advances water and energy infrastructure, and the Eastern Africa Power Pool (EAPP) promotes regional power trade and low-carbon energy transition.

Coordination and Knowledge Sharing

Progress toward integrated regional climate governance is evident in growing cooperation on data, forecasting, and capacity development. Projects such as ACC-LVB and UNEP-WCMC initiatives have strengthened climate information systems and built national capacities to downscale regional data for local use (UNEP, 2019; UNECE, 2023). A central role in this regional climate architecture is played by the IGAD Climate Prediction and Applications Centre (ICPAC), which provides basin-relevant climate prediction, early warning, and applied climate services to all Lake Victoria Basin Partner States (Textbox 7-2). However, cooperation remains largely project-driven and donor-dependent, underscoring the need for sustainable financing and stronger institutional mechanisms to consolidate gains and ensure long-term climate resilience.

Textbox 7-2: The IGAD Climate Prediction and Applications Centre (ICPAC)

The IGAD Climate Prediction and Applications Centre (ICPAC) is a specialized institution of the Intergovernmental Authority on Development (IGAD), mandated to provide climate and weather information services that support sustainable development, disaster risk reduction, and climate resilience across the Greater Horn of Africa, including the Lake Victoria Basin.

Established in 1989 (and formally designated as an IGAD institution in 2003), ICPAC serves as a designated World Meteorological Organization (WMO) Regional Climate Centre (RCC), providing critical climate services to eleven countries in the Greater Horn of Africa, including all Lake Victoria Basin (LVB) riparian states.

For the Lake Victoria Basin Partner States, ICPAC provides a range of critical services, including seasonal climate outlooks, sub-seasonal and extreme weather forecasts, flood and drought early warning, and climate risk assessments relevant to water resources management, agriculture, fisheries, energy, public health, and disaster preparedness. ICPAC also supports the development of climate services for water and hydrometeorological applications, including capacity building, data sharing, regional outlook forums, and the integration of climate information into basin-scale planning and decision-making.

Through these functions, ICPAC plays a key role in strengthening regional climate resilience, enhancing anticipatory action, and supporting evidence-based water resources and environmental management in the Lake Victoria Basin under conditions of increasing climate variability and change.

7.4.2 National Policy and Legislative Landscape

While regional frameworks set the direction, national policies and legislation drive climate action across the Lake Victoria Basin. All five partner states—Kenya, Tanzania, Uganda, Rwanda, and Burundi—have developed national climate strategies aligned with the Paris Agreement and are implementing or preparing National Adaptation Plans (NAPs) to strengthen resilience (UNFCCC, 2025).

National Frameworks and Legal Foundations

Kenya and Uganda lead in institutionalizing climate governance through Climate Change Acts (2016 and 2021), which provide legally binding mandates and structured implementation cycles. Rwanda's 2019 National Environment and Climate Change Policy integrates climate considerations into national development planning, supporting its ambitious NDC target of a 38% emission reduction. Tanzania's 2021–2026 Climate Change Strategy and 2015 Disaster Management Act guide its 30–35% mitigation goal, while Burundi, despite limited capacity, achieved a milestone with its first NAP submission in 2023. Table 7-4 summarizes the main policy instruments, adaptation priorities, and financing needs across the five countries.

> "The EAC Climate Change Policy provides the overarching framework for regional action, aiming to harmonize measures that strengthen climate resilience and sustainable development, particularly through adaptation"

Table 7-4. Comparative Overview of National Climate Policy Frameworks in the Lake Victoria Basin

Country	Primary Legal/Policy Instrument	Key Adaptation Sectors	Estimated Financial Need (USD)	NAP Status
Kenya	Climate Change Act (2016); NCCAP 2023–2027	Agriculture, water, energy, health, infrastructure, DRM, blue economy	62 billion (2020–2030)	NAP (2015–2030) under implementation
Tanzania	National Climate Change Strategy (2021–2026); Disaster Management Act (2015)	Agriculture, water, energy, coastal/marine, health, infrastructure, tourism	19.2 billion	NAP process initiated (2022)
Uganda	National Climate Change Act (2021)	Agriculture, forestry, water, infrastructure, energy, health, DRM	28.1 billion (to 2030)	NAP process launched (2023)
Rwanda	National Environment & Climate Change Policy (2019)	Water, agriculture, forestry/land, settlements, health, transport, mining	~11 billion (to 2030)	NAP advancing; integrated into NDC
Burundi	National Climate Policy; DRR Strategy (2018–2025)	Energy, agriculture, water, health, ecosystems	Not aggregated	First NAP submitted (2023)

Integration of Climate and Disaster Risk Management

A key regional trend is the convergence of climate change adaptation (CCA) and disaster risk reduction (DRR). Kenya's forthcoming Disaster Risk Management Strategy (2025–2030) and Tanzania's updated frameworks align with the Sendai Framework, reflecting recognition that climate impacts often manifest as disasters. However, implementation capacity remains uneven: Rwanda and Kenya operate functional DRR systems at multiple levels, while Tanzania and Uganda continue to strengthen subnational capacity. Burundi faces the greatest challenges due to institutional and financial constraints (SDG Indicators, 2023).

To close these gaps, the *Climate Risk and Early Warning Systems (CREWS) East Africa Project*—launched in 2023 with US$7 million—aims to enhance cross-border data exchange, impact-based forecasting, and coordination between meteorological and disaster agencies, including for Lake Victoria Basin states (WMO, 2023; PreventionWeb, 2023).

Climate Policy Integration and Implementation

All countries have updated their Nationally Determined Contributions (NDCs) combining mitigation and adaptation goals. Rwanda and Kenya demonstrate the most advanced integration, supported by NAPs and Long-Term Low Emission Development Strategies (LEDS). Uganda and Tanzania are progressing toward similar long-term strategies, while Burundi remains at an early stage of policy maturation. The *Community Climate Change Adaptation Assessment (C3A2)* initiative complements national efforts by developing localized adaptation models that feed into the LVBC's Climate Change Action Plan and Strategy.

Figure 7-9 illustrates NDC mitigation targets and financing needs, highlighting disparities in ambition and resource requirements across countries. Overall, while policy frameworks are well aligned with regional and global commitments, implementation remains constrained by financing gaps, institutional weaknesses, and the need for sustained coordination between national and basin-level institutions.

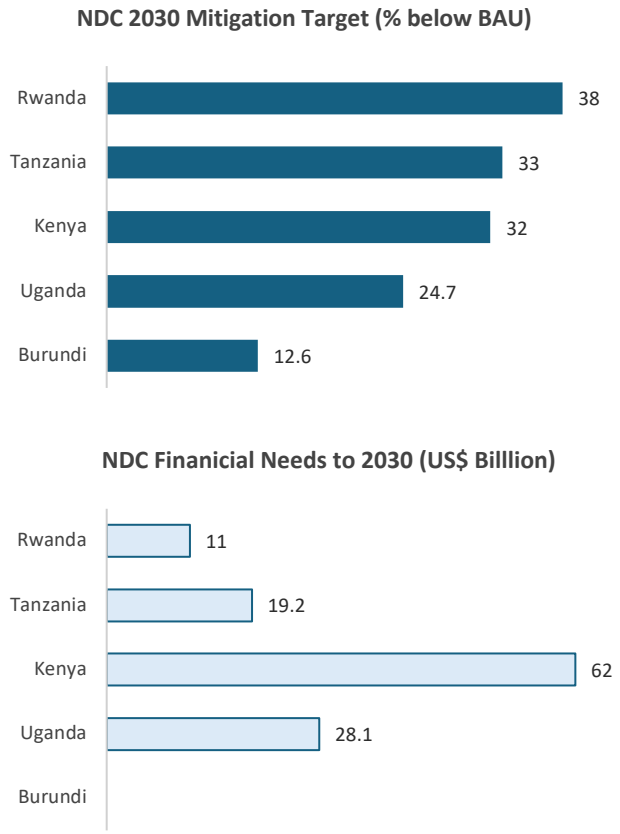


Figure 7-9. *Lake Victoria Basin Countries – NDC mitigation targets and financial requirements*

7.4.3 National Governance and Institutional Architecture

Institutional Foundations for Climate Action

Climate governance in the Lake Victoria Basin rests on distinct yet converging institutional frameworks across Partner States. Each country has established a lead ministry to guide climate policy, an environmental agency to enforce regulation, and emerging coordination platforms to mainstream climate action. However, these institutions often face a "mandate–capacity gap," where expanding responsibilities—such as managing carbon markets and monitoring, reporting, and verification (MRV) systems—outpace available technical and financial resources. Addressing this imbalance is vital for sustained implementation.

National Coordination Structures

- **Kenya:** The Ministry of Environment, Climate Change and Forestry leads policy, supported by the Climate Change Directorate and enforced by the National Environment Management Authority (NEMA), which also acts as the Designated National Authority for carbon markets.
- **Tanzania:** The Vice President's Office (Division of Environment) directs climate policy, with the National Environment Management Council (NEMC) overseeing compliance and international obligations.
- **Uganda:** The Ministry of Water and Environment coordinates action through NEMA and the National Climate Change Advisory Committee, established under the 2021 Climate Change Act.
- **Rwanda:** The Ministry of Environment formulates policy, implemented by the Rwanda Environment Management Authority (REMA) to integrate climate considerations across sectors.
- **Burundi:** The Ministry of Environment, Agriculture and Livestock (MINEAGRIE) leads climate initiatives, while the National Platform for Risk Prevention and Disaster Management manages disaster risk reduction.

Decentralization and Local Leadership

Local-level engagement is increasingly recognized as essential for effective adaptation. Kenya's County Climate Change Funds (CCCFs) exemplify best practice by financing locally identified priorities. Uganda's Climate Change Act (2021) similarly mandates District Climate Action Plans, integrating climate measures into local development. Despite these advances, sub-national institutions across the Basin still require enhanced technical expertise and predictable financing to fully operationalize locally led climate governance.

7.4.4 The Climate Finance Landscape

Financing the Basin's Climate Ambition

Achieving the climate commitments of the Lake Victoria Basin demands large-scale and predictable finance. Yet, the region faces a wide gap between needs and available resources, with heavy dependence on international funding and limited private-sector engagement. Collectively, the five Basin countries require more than USD 130 billion to meet their NDC targets by 2030—most of it conditional on external support (Republic of Rwanda, 2020). This mirrors a continental pattern, with Africa projected to face climate costs of USD 290–440 billion by 2030 (AfDB, 2023; UNEP, 2023).

Sources and Mechanisms of Climate Finance

Climate finance in the Basin draws from multilateral, bilateral, and domestic sources. Multilateral funds—such as the Green Climate Fund (GCF), Global Environment Facility (GEF), and Adaptation Fund (AF)—remain central, supporting initiatives like the transboundary *Adaptation to Climate Change in the Lake Victoria Basin (ACC-LVB)* project. Bilateral partnerships—such as Germany's support to Rwanda, Kenya, and Uganda—complement these efforts with technical and financial cooperation. At the national level, Rwanda's Green Fund (FONERWA) has mobilized over USD 130 million, while Kenya's County Climate Change Funds (CCCFs) and Uganda's Climate Finance Unit are advancing local and pipeline financing, respectively.

Innovative and Private-Sector Financing

Public finance alone cannot bridge the climate gap. Innovative instruments are increasingly used to attract private investment. ***Blended finance*** initiatives like **Aceli Africa** lower risks for lending to green SMEs across Kenya, Rwanda, Tanzania, and Uganda. ***Public–Private Partnerships (PPPs)*** are being applied to develop climate-resilient infrastructure, while national ***green finance frameworks***—including Kenya's and Rwanda's taxonomies and Uganda's exploration of green bonds—aim to align financial systems with sustainability objectives (EIB, 2023). These innovations signal growing policy momentum toward diversified, inclusive, and resilient climate finance systems across the Basin.

7.4.5 Synthesis and Strategic Recommendations

Synthesis of the Enabling Framework

The Lake Victoria Basin's climate governance architecture reflects strong ambition but persistent structural and financial constraints. Partner States have aligned with the EAC's regional climate and environment policy framework and advanced national strategies and NDCs that increasingly integrate adaptation, disaster risk reduction, and local action. Innovative models such as Kenya's ***County Climate Change Funds (CCCFs)*** and Rwanda's ***Green Fund (FONERWA)*** show how devolved and results-based mechanisms can build institutional capacity and community resilience.

Despite these advances, key challenges endure. Regional cooperation remains fragmented and donor-driven, national legislative maturity varies, and implementation agencies face widening "mandate–capacity" gaps. Financing needs—exceeding USD 130 billion to 2030—far outstrip available flows, leaving the Basin's climate ambition vulnerable to global funding fluctuations. The long-term solution lies in greening financial systems and mobilizing private investment through predictable, well-governed frameworks.

Strategic Recommendations

Policy and Legislation

- Fast-track the domestication of EAC environmental and climate protocols to create binding regional obligations.
- Support Partner States lacking climate legislation to enact statutory frameworks that enhance accountability and investor confidence.

Governance and Institutions

- Strengthen the **LVBC's** mandate and resources to coordinate basin-wide climate governance, data systems, and knowledge sharing.
- Build institutional capacity in national environment authorities and climate directorates, focusing on climate finance, MRV, and carbon market oversight.
- Expand devolved governance by adapting Kenya's CCCF model across the Basin and promoting regional learning exchanges.

Finance and Investment

- Establish a **regional project-preparation facility** to generate bankable transboundary projects.
- Accelerate the **greening of national financial systems,** including green taxonomies, disclosure standards, and green/blue bond markets.
- Develop a **regional blended-finance platform** to leverage concessional and private capital for renewable energy, resilient agriculture, and ecosystem restoration.

7.5 Building Resilience: Climate Change Adaptation

This section explores how the Lake Victoria Basin is responding to escalating climate risks through a range of adaptation measures that strengthen environmental, institutional, and community resilience. It reviews current strategies—including infrastructure upgrades, early warning systems, and nature-based and community-led initiatives—and assesses their effectiveness across the five Partner States. The section also outlines major adaptation programs and policy frameworks, identifies key challenges such as limited finance, weak coordination, and data gaps, and concludes with strategic recommendations for scaling up action through a coherent, basin-wide resilience framework led by the Lake Victoria Basin Commission (LVBC).

7.5.1 Current Adaptation Strategies and Practices

Adaptation as a Core Development Priority

The Lake Victoria Basin (LVB) is entering a phase of heightened climate stress marked by rising temperatures, erratic rainfall, and recurrent floods and droughts. These changes are disrupting water resources, agriculture, fisheries, energy, transport, and public health (World Bank, 2025a; WMO, 2023). For its 45 million residents, adaptation has become an existential and development priority. Partner States and their development partners—through the LVBC, AfDB, World Bank, UNEP, and KfW—are working to strengthen resilience through integrated, multi-level interventions that combine infrastructure, institutional reform, and community-based innovation.

Infrastructural Measures

Hard investments remain essential for mitigating direct climate impacts. Kenya's Nyando River flood-control works and the AfDB-financed CRESTI-LVB project are improving flood protection, navigation safety, and climate-proofed maritime infrastructure across the basin. These initiatives highlight a growing recognition that resilience requires basin-wide planning to link upstream water storage, watershed management, and downstream protection. Urban water and sanitation systems are also being upgraded under various national programs to improve water quality and public health.

Institutional and Policy Frameworks

Climate adaptation in the LVB increasingly relies on coherent governance and coordinated policy frameworks. All Partner States have prepared or updated National Adaptation Plans (NAPs) to mainstream resilience into national development

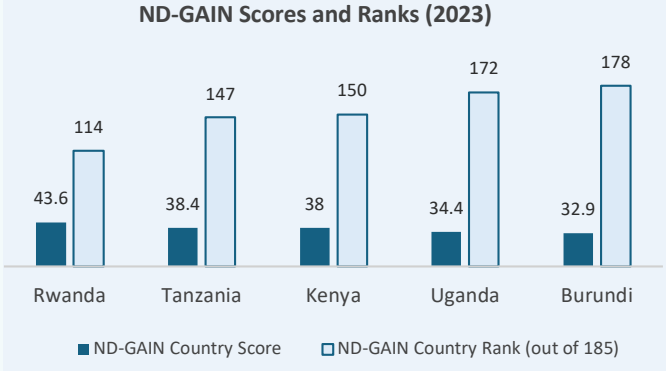
planning (see Section 7.4.2). Regionally, the LVBC Climate Change Adaptation Strategy and Action Plan (2018–2023) provides a transboundary coordination mechanism for aligning these national efforts. Complementing it, the World Bank-supported Lakewide Inclusive Sanitation (LWIS) Strategy offers a regional policy and investment framework to guide improvement of sanitation systems and reduction of lake pollution—both critical for climate-resilient water management and public health protection.

Despite this growing institutional maturity, adaptive capacity remains uneven. As shown in Textbox 7-2, the ND-GAIN Index places Rwanda highest in readiness due to stronger governance and financial systems, while Burundi and Uganda face higher vulnerability linked to limited fiscal and institutional capacity. Bridging this readiness gap requires greater policy harmonization and sustained investment in shared regional systems.

Textbox 7-3: ND-GAIN Index and Climate Change Adaptation in the Lake Victoria Basin

The Notre Dame Global Adaptation Initiative (ND-GAIN) Index measures countries' vulnerability to climate change and their readiness to adapt. It combines 36 indicators across six vulnerability sectors (food, water, health, ecosystem services, human habitat, and infrastructure) and three readiness dimensions (economic, governance, and social). Higher scores indicate greater capacity to adapt and lower relative vulnerability. The 2023 ND-GAIN scores for Lake Victoria Basin countries show marked disparities as shown in the figure below. These results highlight the urgent need for coordinated basin-wide adaptation.

ND-GAIN Scores



ND-GAIN Scores

Country	Vulnerability Score	Readiness Score
Burundi	0.553	0.211
Kenya	0.500	0.261
Rwanda	0.567	0.439
Tanzania	0.516	0.285
Uganda	0.536	0.224

(Source: ND-GAIN, 2023)

(Source: ND-GAIN, 2023)

Burundi, Uganda, and Kenya fall in the high-vulnerability/low-readiness quadrant, with acute risks in food security and health, reflecting structural fragilities and limited institutional capacity. Tanzania shows slightly better readiness, though still constrained by water sector vulnerabilities. Rwanda, while among the 20 most vulnerable countries globally, demonstrates comparatively higher readiness, supported by stronger institutions and adaptation frameworks. Socioeconomic constraints—low GDP per capita and modest human development indices—limit national investments in resilience. Community-based approaches such as agroforestry, biogas, and climate-smart agriculture, championed by initiatives like the Adapting to Climate Change in Lake Victoria Basin (ACC-LVB) project, are therefore critical (ACC-LVB, 2023).

The variation in readiness across basin countries underscores the importance of regional collaboration. Knowledge sharing, policy harmonization, and joint investment in water resource management through the Lake Victoria Basin Commission can help close adaptation gaps and strengthen collective resilience.

Early Warning Systems and Climate Services

Weather and climate services remain among the basin's most cost-effective adaptation tools. The **HIGHWAY Project** (Textbox 7-3) demonstrated the power of regional cooperation through a lake-wide early warning system co-designed with fisherfolk, reducing storm-related fatalities by roughly 30 percent and delivering annual benefits exceeding US$ 40 million (WMO, 2023). Its success has catalyzed the **CREWS initiative** and national hydromet upgrades that extend flood and drought warnings to most districts, though Burundi and northern Tanzania still exhibit coverage gaps.

Textbox 7-4: Saving Lives through Regional Early Warning – The HIGHWAY Project

The High Impact Weather Lake System (HIGHWAY) project stands out as a transformative institutional adaptation in the Lake Victoria Basin. Before its implementation, between 3,000 and 5,000 people—mostly fisherfolk—lost their lives every year to sudden, violent storms on the lake (World Meteorological Organization [WMO], 2021; Beverly et al., 2019). At the time, no operational regional early warning system existed to protect them.

Led by the WMO, the project brought together the National Meteorological and Hydrological Services of Kenya, Rwanda, Tanzania, and Uganda to design a harmonized marine forecasting system (WMO, 2021). What made HIGHWAY distinctive was its participatory approach: forecasts were co-designed with fishing communities to ensure they were understandable, trusted, and directly relevant to safety needs. Dissemination relied on multiple, accessible channels, from radios and flags at landing sites to social messaging applications.

The outcomes have been striking. Independent studies confirm a 30% reduction in weather-related deaths, saving more than 300 lives annually (WMO, 2021; 2023). The system's annual economic benefits are estimated at US$ 44 million, with a benefit-to-cost ratio of 16:1—an extraordinary return on investment. More than 200,000 people have directly benefited, while indirect beneficiaries exceed 1.4 million (WMO, 2021).

The HIGHWAY experience underscores the life-saving potential of regional cooperation and people-centered design in adaptation. By combining scientific expertise with local knowledge, the project has created a durable model for strengthening climate services and protecting vulnerable communities across the basin.

Nature-Based Solutions and Community-Level Adaptation

Healthy ecosystems provide vital natural defenses against climate hazards. The **ACC-LVB Project** in Burundi (Textbox 7-5) has restored wetlands and hill slopes through reforestation, terracing, and sustainable energy use, improving soil stability, doubling crop yields, and reducing firewood demand by 97 percent. Across the basin, such ecosystem-based and **climate-smart agriculture (CSA)** practices are being scaled up to enhance water retention, soil fertility, and food security for smallholders while preserving biodiversity.

Textbox 7-4: Ecosystem-Based Adaptation in Burundi (ACC-LVB Project)

The Adaptation to Climate Change in Lake Victoria Basin (ACC-LVB) project in Burundi illustrates how comthe erosion-prone provinces of Kirundo and Muyinga—part of Lake Victoria's upper catchment—the project focused on tackling land degradation, a major driver of vulnerability and declining downstream water quality.

In partnership with local farming cooperatives, the project supported the planting of over 230,000 trees, including avocado and grevillea, to stabilize soils and diversify incomes (UNEP, 2023). Farmers constructed radical terraces across 240 hectares of farmland, reinforced with elephant grass to halt erosion and landslides. To curb deforestation linked to fish processing, an innovative fish-drying kiln was introduced, reducing firewood use by 97% while improving product quality.

The impacts have been transformative. Terraces improved soil moisture and more than doubled yields of staples such as beans and cassava, strengthening food security (UNEP, 2023). The efficient kilns protected forests and increased fish market value by 50%, boosting incomes. Notably, fishers downstream observed clearer waters, underscoring the interconnectedness of basin ecosystems.

How aligning ecosystem restoration with livelihood benefits secures community ownership and produces multiple co-benefits. Yet it also underscores the need for sustained support to maintain terraces and new technologies. Overall, the Burundi experience demonstrates the power of locally grounded, nature-based solutions to deliver both local and transboundary adaptation gains.

Social and Financial Innovations

Strengthening social resilience is equally important. Capacity-building under ACC-LVB has improved use of localized climate forecasts, enabling better on-farm decisions. Livelihood diversification—through aquaculture, beekeeping, and efficient fish-drying technologies—has reduced dependence on rain-fed farming and protected forests. The **CRESTI-LVB** project's micro-grants for women and youth demonstrate how targeted finance can link adaptation with inclusive growth, although climate insurance and concessional funding remain limited in reach.

Indigenous and Local Knowledge (ILK)

Indigenous and Local Knowledge remains a valuable but under-utilized resource. Communities continue to rely on traditional indicators for forecasting, water harvesting, and agroecological management. Integrating ILK early in project design—rather than only at implementation—can ensure that adaptation solutions are context-appropriate, socially legitimate, and sustainable. The **ACC-LVB** experience illustrates how combining ILK with scientific data can improve outcomes and strengthen community ownership.

Overview of Major Adaptation Initiatives

Table 7-5 presents key adaptation programs in the LVB, showing how infrastructural, institutional, social, and nature-based approaches are increasingly being implemented in a coordinated, multi-stakeholder manner.

Table 7-5. Inventory of Major Climate Change Adaptation Projects and Initiatives in the Lake Victoria Basin

Project/ Initiative Name	Lead/Executing Agency & Key Partners	Partner Countries	Primary Adaptation Category	Key Objectives & Interventions
Adapting to Climate Change in Lake Victoria Basin (ACC-LVB)	LVBC, UNEP, Adaptation Fund	Burundi, Kenya, Rwanda, Tanzania, Uganda	Hybrid (NbS, Institutional, Social/Financial)	Strengthen institutional capacity and implement community-based Ecosystem-based Adaptation (EbA) and Climate-Smart Agriculture (CSA) (UNEP, 2024; Lake Victoria Basin Commission, n.d.-a).
High Impact Weather Lake System (HIGHWAY) Project	WMO, FCDO	Kenya, Rwanda, Tanzania, Uganda	Institutional, Social	Establish a regional Early Warning System (EWS) co-designed with fisherfolk to reduce weather-related accidents and fatalities on the lake (World Meteorological Organization, 2021; World Meteorological Organization, 2023).
Lakewide Inclusive Sanitation (LWIS) Strategy	World Bank, LVBC, Partner States	Burundi, Kenya, Rwanda, Tanzania, Uganda	Infrastructural, Institutional	Develop sustainable, climate-resilient sanitation infrastructure and services for over 100 urban areas to improve water quality and public health (World Bank, 2025b; World Bank, 2024).
Climate Resilience for Sustainable Maritime Transport Infrastructure (CRESTI-LVB)	AfDB, LVBC	Kenya, Tanzania, Uganda, Rwanda and Burundi	Infrastructural, Institutional	Enhance the climate resilience of maritime transport infrastructure, including landing sites, and establish a regional climate advisory service hub (African Development Bank Group, 2025).
Scaling up Hydro-meteorological and Early Warning Services	CREWS, WMO, UNDRR, World Bank	Burundi, Kenya, Rwanda, South Sudan, Tanzania, Uganda	Institutional, Social	Build on the HIGHWAY project to scale up impact-based, people-centered EWS for floods and droughts across the broader region (World Meteorological Organization, 2023).
Lake Victoria Basin Integrated Water Resources Management Programme (LVB IWRMP)	LVBC, EU, KfW	Burundi, Kenya, Rwanda, Tanzania, Uganda	Institutional, Infrastructural	Strengthen transboundary integrated water resource management (IWRM) and invest in wastewater disposal infrastructure (Lake Victoria Basin Commission, n.d.-b; NBI Secretariat, 2021).

7.5.2 Challenges and Gaps in Adaptation

Despite growing momentum in climate adaptation, the Lake Victoria Basin (LVB) continues to face structural barriers that constrain basin-wide resilience. These include chronic financing shortfalls, weak institutional coordination, limited data and knowledge systems, and the persistent risk of maladaptation. Overcoming them will require sustained political will, stronger governance, and better integration of adaptation across all development sectors.

Financial and Institutional Barriers

The most critical challenge remains the gap between adaptation needs and available finance. Global funds such as the Adaptation Fund and Green Climate Fund provide essential support, yet allocations remain far below requirements and often misaligned with basin-level priorities (UNEP, 2023). Consequently, investments tend to favor specific thematic areas—like water or ecosystem restoration—while other urgent sectors such as sanitation, health, and urban infrastructure receive limited attention.

At the community level, high borrowing costs and low access to credit hinder smallholders, fishers, and women entrepreneurs from adopting resilient technologies, perpetuating dependence on climate-sensitive livelihoods. Institutional weaknesses compound these financial constraints. Adaptation demands coordination among ministries and between local and regional agencies, yet fragmented mandates and limited capacity within the LVBC and national institutions lead to duplication and inefficiency (LVBC, 2019). While National Adaptation Plans (NAPs) and the LVBC's Climate Change Adaptation Strategy provide a sound policy foundation, mainstreaming them into sectoral plans and budgets remains uneven.

Knowledge and Scalability Gaps

Reliable data and climate information services are fundamental to adaptation, yet remain inconsistent across the basin. Downscaled forecasts, impact assessments, and localized knowledge products are still scarce, leaving planners and communities with limited actionable information (UNEP & LVBC, 2018). Projects such as ACC-LVB have pioneered local forecasting and ecosystem-based approaches, but the capacity to replicate these innovations basin-wide remains limited.

Scaling up remains a persistent weakness. Many successful pilots—such as ecosystem-based adaptation in Burundi—have not transitioned into sustained, regionally coordinated programs. This "pilot project trap" reflects both inadequate long-term financing and the absence of mechanisms to integrate lessons learned into mainstream policy and investment planning.

Risks of Maladaptation

Insufficient adaptation support can drive households toward coping strategies that undermine long-term resilience—selling livestock, withdrawing children from school, or resorting to charcoal production when harvests fail (Marcus et al., 2023). Such short-term responses erode natural resources and deepen poverty cycles. Effective adaptation must therefore go beyond technical fixes to address underlying social and economic vulnerability. Integrating climate action with poverty reduction, livelihood diversification, and social protection policies is essential to expand sustainable choices for communities and prevent maladaptive outcomes.

7.5.3 Conclusion and Strategic Recommendations

The Lake Victoria Basin stands at a pivotal juncture in its response to climate change. A solid foundation for adaptation has been established through a growing portfolio of initiatives—ranging from regional early warning systems to community-driven ecosystem restoration—that demonstrate both feasibility and impact. Projects such as the HIGHWAY early warning system and the ACC-LVB nature-based interventions in Burundi illustrate that integrated, locally grounded resilience is achievable. Yet progress remains uneven. Chronic underfinancing, fragmented mandates, limited institutional capacity, and weak data systems continue to

hinder basin-wide transformation, leaving many communities exposed to climate shocks and maladaptive practices.

To consolidate gains and scale up success, adaptation in the basin must shift from project-based initiatives to a coordinated regional framework led by the Lake Victoria Basin Commission (LVBC). Six strategic priorities emerge from this assessment:

1. **Strengthen Transboundary Governance** – Elevate the LVBC's coordinating role to a comprehensive regional adaptation framework that promotes cross-sectoral collaboration and alignment between water, agriculture, health, and infrastructure policies.
2. **Diversify and Sustain Climate Finance** – Develop a broader financing base through the Green Climate Fund, bilateral partnerships, and blended public–private mechanisms, ensuring resources also reach local governments and communities.
3. **Establish a Regional Climate Knowledge Hub** – Institutionalize a basin-wide platform to generate, downscale, and disseminate actionable climate information, linking data to decision-making in planning, agriculture, and disaster risk management.
4. **Integrate Indigenous and Local Knowledge (ILK)** – Embed community knowledge within adaptation planning and implementation to co-create context-specific and socially grounded solutions.
5. **Scale Up Nature-Based Solutions (NbS)** – Expand successful models of ecosystem restoration, reforestation, peatland restoration, wetland restoration, littoral buffer restoration, soil and water conservation, climate-smart agriculture and groundwater recharge demonstrated under the ACC-LVB project and elsewhere in the world to other vulnerable sub-basins.
6. **Embed Livelihood Resilience** – Mainstream livelihood diversification and social protection into all adaptation interventions to reduce poverty-driven vulnerability and prevent maladaptation.

Implementing these priorities would transform adaptation from isolated projects into a basin-wide resilience program. A coherent, adequately financed, and knowledge-driven approach—anchored in both science and local experience—offers the most sustainable path to protecting the basin's ecosystems and securing the well-being of its 45 million people.



7.6 Contributing to the Solution: Climate Change Mitigation

This section explores how the Lake Victoria Basin (LVB) and its five riparian countries—Burundi, Kenya, Rwanda, Tanzania, and Uganda—are advancing climate change mitigation within a low-emission, high-vulnerability context. It first outlines the greenhouse gas emissions profile (Section 7.6.1), highlighting sectoral patterns dominated by agriculture, forestry, and land use (AFOLU). It then presents a speculative basin-wide profile (Section 7.6.2), combining national data with the Basin's unique ecological and socio-economic features to identify key emission hotspots such as peatlands, wetlands, and urban centers. The final part examines the mitigation potential and ongoing efforts (Section 7.6.3), focusing on ecosystem carbon stocks, national NDC commitments, renewable energy transitions, circular waste systems, and green transport. Together, these analyses show how the Basin can harness its natural assets and policy frameworks to align regional development with global decarbonization goals.



7.6.1 Greenhouse Gas Emissions Profile of the Lake Victoria Basin Countries

Scale and Structure

The five Lake Victoria Basin (LVB) countries—Burundi, Kenya, Rwanda, Tanzania, and Uganda—together emit about **290–320 MtCO_2e annually**, representing less than 1 percent of global totals (AfDB, 2023). Despite their low global share, these countries face **disproportionate exposure to climate risks**, from floods to droughts, highlighting the urgency of linking mitigation with adaptation. Tanzania contributes the largest share, followed by Kenya, Uganda, Rwanda, and Burundi, largely reflecting differences in population, land area, and economic structure (Figure 7-10; Figure 7-11; Table 7-6). Average per capita emissions range between 0.6 and 1.5 tCO_2e per person, compared with the global mean of ~6.5 tCO_2e (World Bank, 2024). This underlines the region's low industrial base but also points to the rapid growth of sectors that could increase emissions in the future.

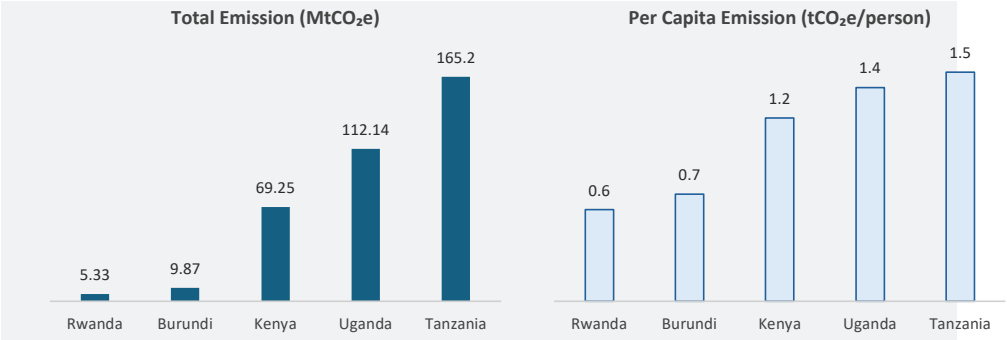


Figure 7-10. *Total and per capita GHG emissions of the LVB countries*

Table 7-6. National total emissions and sectoral shares (most recent official years)

Country	Inventory Year	Total ($MtCO_2e$)	AFOLU (Mt-CO_2e, %)	Energy (Mt-CO_2e, %)	IPPU (Mt-CO_2e, %)	Waste (Mt-CO_2e, %)
Burundi	2015	9.87	8.90 (90.2%)	0.59 (6.0%)	0.05 (0.5%)	0.33 (3.3%)
Kenya	2019	69.25	45.47 (65.7%)	17.65 (25.5%)	3.12 (4.5%)	3.01 (4.3%)
Rwanda	2018	5.33	3.15 (59.1%)	1.05 (19.7%)	0.65 (12.2%)	0.48 (9.0%)
Tanzania	2021	165.20	132.40 (80.1%)	22.60 (13.7%)	3.60 (2.2%)	6.60 (4.0%)
Uganda	2019	112.14	85.22 (76.0%)	10.21 (9.1%)	0.45 (0.4%)	16.26 (14.5%)

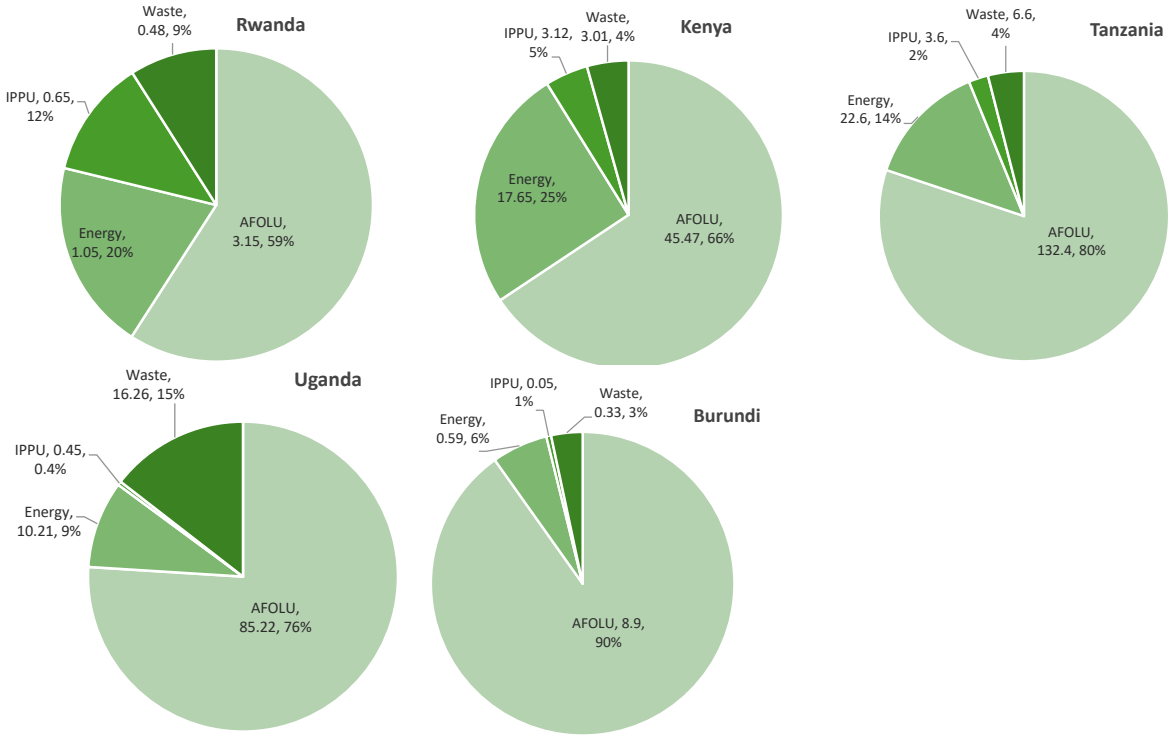


Figure 7-11. *Sectoral share in the total GHG emission ($MtCO_2e$/year; %) per LVB country (compiled from official reports of the LVB countries)*

Sectoral Composition and Trends

Across the Basin, the **Agriculture, Forestry, and Other Land Use (AFOLU)** sector dominates emissions, accounting for 55–90 percent of national totals (Table 7-6; Figure 7-12). The main drivers include:

- **Livestock methane (CH_4)** from enteric fermentation in cattle, sheep, and goats;
- **Nitrous oxide (N_2O)** emissions from the use of fertilizers and manure; and
- **Carbon dioxide (CO_2)** from deforestation, peatland degradation, and wetland conversion.

These trends reflect the Basin's dependence on smallholder agriculture, expansion of cropland into forests, and the heavy use of biomass for energy. The **energy sector** (10–25 percent) is the second-largest source, dominated by fossil-fuel combustion in transport and by charcoal and firewood use for household cooking. Urbanization and industrial growth are slowly diversifying energy demand, while Kenya's expansion of geothermal, wind, and solar generation shows the potential to decouple growth from emissions (World Bank, 2024).

The **waste sector** (5–10 percent) is an emerging source of methane from unregulated dumpsites and untreated wastewater, reflecting the pressures of fast-growing urban populations. The **industrial processes and product use (IPPU)** sector remains small (<5 percent), but its contribution is expected to rise with the region's industrialization. Overall, emissions in the Basin are rising at an estimated 2–3 percent annually, led by Tanzania and Uganda, due to agricultural expansion, deforestation, and increased fossil-fuel consumption (AfDB, 2023; FAO, 2023).

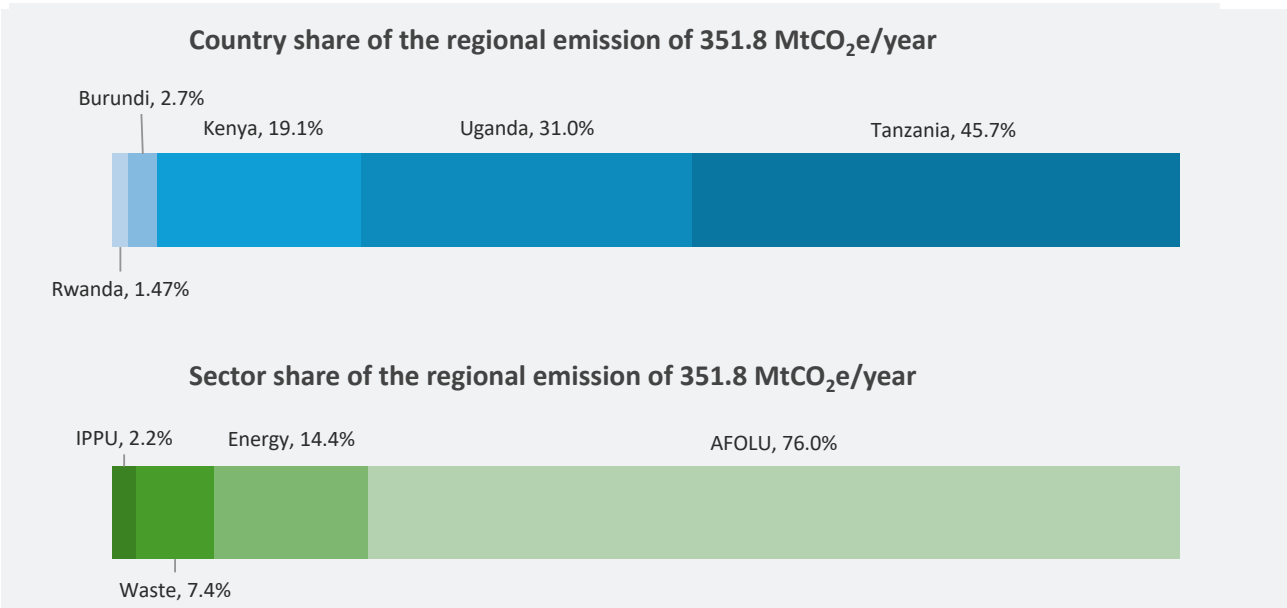


Figure 7-12. *Country and sectoral share of the total regional GHG emission (compiled from official reports of the LVB countries).*

Key Insights and Policy Implications

As summarized in Textbox 7-6, the Basin's GHG profile reveals both low absolute emissions and high mitigation potential. The AFOLU sector offers the greatest opportunity through climate-smart agriculture, agroforestry, livestock management, and forest conservation (IPCC, 2022; FAO, 2023). Rapid urbanization calls for improved waste management, methane capture, and circular-economy solutions. Meanwhile, scaling up renewable energy and clean cooking technologies could significantly curb biomass dependence and reduce deforestation.

Textbox 7-6: Key Insights on the GHG Emissions Profile of the LVB Countries

Understanding the greenhouse gas (GHG) profile of the Lake Victoria Basin is central to designing effective mitigation strategies. While total emissions are modest on a global scale, the sectoral structure of emissions reveals clear patterns that highlight both challenges and opportunities for climate action. The following insights, derived from the most recent national inventories and authoritative global sources, summarize the basin's emissions dynamics and their implications for policy.

Key Insights

1. **AFOLU (agriculture, forestry and other land use) dominates emissions and offers the greatest mitigation potential.** Agriculture, forestry, and other land use (AFOLU) account for the majority of emissions in all five countries, largely from livestock (methane), croplands (nitrous oxide), and deforestation (carbon dioxide). This underscores the centrality of climate-smart agriculture, improved livestock management, and sustainable forest protection as the basin's greatest mitigation opportunities (IPCC, 2022; FAO, 2022).
2. **Energy emissions are rising with economic growth.** While still smaller than AFOLU, the energy sector is growing in importance, driven by transport and fossil-fuel electricity generation—especially in Tanzania and Kenya. Kenya's rapid expansion of renewables demonstrates the potential to moderate energy-related emissions even as demand increases (World Bank, 2024).
3. **Urbanization is intensifying waste-related emissions.** Methane from open dumpsites and untreated wastewater is an emerging source, reflecting rapid urban growth and inadequate waste management systems. Addressing this requires investments in sanitary landfills, methane capture, and circular economy approaches. (World Bank, 2022).
4. **Industrial emissions remain limited but will expand.** Industrial Processes and Product Use (IPPU) currently contribute less than 5% of totals, reflecting low levels of industrialization. However, its share is expected to grow as countries industrialize, highlighting the need for early adoption of efficient, low-carbon technologies.
5. **Per capita emissions remain low but totals are climbing.** At **0.6–1.5 tCO_2e per person**, emissions are far below the global average of ~6.5 tCO_2e. However, rapid population growth, urban expansion, and accelerating land-use change are steadily driving up absolute totals, adding pressure to natural systems and amplifying the urgency of targeted mitigation.

Looking ahead, managing emissions growth while promoting development will require integrated basin-wide monitoring and coordinated action among the five countries. A harmonized GHG inventory system, facilitated by the Lake Victoria Basin Commission, would enhance transparency, enable comparison of sectoral progress, and guide transboundary mitigation strategies aligned with regional and global climate commitments.

7.6.2 A Speculative Greenhouse Gas Emission Profile of the Lake Victoria Basin

Bridging the Data Gap

The absence of a harmonized, basin-wide greenhouse gas (GHG) inventory makes it difficult to quantify emissions specific to the Lake Victoria Basin (LVB). This section provides a deductive, evidence-based hypothesis of the Basin's GHG profile by integrating national data (Section 7.6.1) with the Basin's unique ecological and socio-economic features discussed in Chapter 2. The aim is both to guide policy dialogue and to underscore the urgency of establishing a formal, spatially explicit GHG inventory under the Lake Victoria Basin Commission (LVBC).

Dominance of the AFOLU Sector

Agriculture, Forestry and Other Land Use (AFOLU) is likely to account for **over 80 percent of total emissions** within the Basin—an even higher share than national averages. Dense rural populations, rapid land conversion, and dependence on biomass energy have intensified pressures on forests, grasslands, and wetlands.

- **Deforestation and land-use change** release large amounts of CO_2, as cropland expansion and fuelwood demand continue to degrade natural vegetation (FAO, 2020; Li et al., 2024).
- **Livestock and fertilizer use** generate significant methane (CH_4) and nitrous oxide (N_2O), with emission intensities per livestock product among the highest in Africa (Belete, 2023; FAO, 2023).
- **Peatland degradation** in Uganda and western Tanzania is a critical hotspot. Drained peat can emit up to 99 tCO_2 per hectare per year, making it one of the most potent local sources and a priority for conservation (Farmer et al., 2022; IUCN, 2021).

Emerging Urban and Aquatic Sources

Although smaller in scale, **urban and aquatic systems** are rapidly becoming important emitters. Cities such as **Kampala** and **Kisumu** exhibit divergent GHG signatures—waste and sanitation dominate in Kampala, while transport is the leading source in Kisumu but with a strong component of waste (UN-Habitat, 2013; ITDP, 2021). These trends highlight the need for tailored mitigation approaches focusing on waste management, biogas, electrified mobility, and clean cooking.

Meanwhile, Lake Victoria itself is emerging as a methane source. Persistent eutrophication from agricultural runoff and sewage has created anoxic zones where microbial decomposition releases CH_4. Research shows that eutrophic tropical lakes emit exponentially more methane than temperate ones (Beaulieu et al., 2019; Borges et al., 2022). Reducing nutrient inflows and restoring wetlands thus yields both water-quality and climate co-benefits.

A Hypothesized Basin Profile

Drawing from these patterns, the speculative profile summarized in **Table 7-7** highlights the Basin's distinctive emission landscape. The LVB's GHG footprint is characterized by:

1. Intensified **AFOLU emissions** from land conversion, livestock, and fertilizer use.
2. High-intensity **peatland CO_2 hotspots** that could dominate the regional carbon budget.
3. Expanding **urban methane and CO_2 emissions** linked to transport and waste.
4. A significant though under-recognized **aquatic methane flux** from Lake Victoria's eutrophic waters.

Table 7-7. Speculative Greenhouse Gas Emission Profile of the Lake Victoria Basin

Basin Driver	Main Emission Source	Dominant GHG	Relative Significance	Key vidence
Agricultural expansion, fuelwood demand	Deforestation & land-use change	CO_2	Very High	FAO (2020); Li et al. (2024)
High livestock density, fertilizer use	Livestock & soils	CH_4, N_2O	High	Belete (2023); FAO (2023)
Peatland drainage	Degraded peatlands	CO_2	Very High (Hotspot)	Farmer et al. (2022); IUCN (2021)
Rapid urbanization	Waste & sanitation	CH_4	High (Local)	UN-Habitat (2013)
Motorization	Urban transport	CO_2	High (Local)	ITDP (2021)
Eutrophication	Lake surface	CH_4	Medium	Beaulieu et al. (2019); Borges et al. (2022)

7.6.3 Mitigation Potential and Current Efforts

Carbon Stocks and Ecosystem Sequestration

The Lake Victoria Basin's (LVB) highest-leverage mitigation assets are forests, wetlands, and peatlands. Intact montane and lowland forests (e.g., Mau, Nyungwe, Minziro–Sango Bay) typically store ~130–150 t C/ha and can sequester ~2–5 t C/ha/yr during regrowth, offering fast "no-regret" gains through protection and assisted natural regeneration (Hubau et al., 2020). Papyrus wetlands combine very high productivity with long-term peat burial (stocks often >700 t C/ha), though part of gross uptake is offset by CH_4 fluxes—underscoring the value of keeping systems waterlogged. The peatland complex spanning Kagera, Rweru–Akanyaru, and Sango Bay–Minziro holds regionally and globally significant carbon; drainage rapidly flips these sinks to sources with >20 t CO_2/ha/yr losses (NBI, 2019; IUCN, 2021). Table 7-8 summarizes indicative stocks and sequestration rates and underscores peat conservation and rewetting as the Basin's single most powerful mitigation lever.



Table 7-8. Summary of Climate Change Mitigation Commitments in the Nationally Determined Contributions (NDCs) of the Lake Victoria Basin Partner States (sourced from the updated NDCs and Burundi, 2021; Kenya, 2020; Rwanda, 2020; Tanzania, 2021; Republic of Uganda, 2022).

Commitment Category	Burundi	Kenya	Rwanda	Tanzania	Uganda
Headline GHG Reduction Target (vs. BAU by 2030)	20% (3% unconditional, 17% conditional)	32% (unconditional/conditional split not specified in the same way)	38% (16% unconditional, 22% conditional)	30-35% (conditional on support)	24.7% (conditional on support)
Key Mitigation Priority Sectors	Energy, AFOLU, Waste, IPPU	Energy, Transport, Industry, Agriculture, Forestry, Waste	Energy, IPPU, Waste, Agriculture	Energy, Transport, Forestry, Waste	AFOLU, Energy, Waste, IPPU, Transport
Specific Targets/Actions in AFOLU	Increase forest cover; promote agro-silvo-pastoral systems.	Promote climate-smart agriculture; increase tree cover to 10% of land area.	Implement soil conservation measures; improve livestock and manure management.	Enhance participatory forest management; promote forest landscape restoration.	Increase forest cover to 21%; restore wetlands; promote climate-smart agriculture.
Specific Targets/Actions in Energy	Develop hydro and solar power; promote improved cookstoves and biogas.	Expand geothermal, solar, and wind power; enhance energy efficiency.	Develop grid-connected hydro and solar; disseminate efficient cookstoves.	Promote diverse renewables (geothermal, wind, solar); expand natural gas use.	Increase renewable energy generation; promote industrial energy efficiency.
Specific Targets/ Actions in Waste	Develop waste-to-energy plant in Bujumbura.	Develop waste-to-energy facilities; improve wastewater management.	Utilize landfill gas for power; develop aerobic composting and wastewater treatment.	Promote waste-to-energy; implement landfill gas recovery.	Implement "Green Cities" waste management; promote biogas from school latrines.
Specific Targets/ Actions in Transport	Develop public transport using large buses.	Develop mass rapid transit systems; promote non-motorized transport.	Implementvehicle emissions standards; develop public transport infrastructure and EVs.	Promote low-emission mass rapid transport (e.g., BRT); promote non-motorized transport.	Improve road transport fuel efficiency; develop non-motorized transport and rail.
Stated Financial Need for Implementation	~$1.69 billion	~$62 billion (2020-2030)	~$11 billion (2021-2030)	~$19.2 billion	~$29.3 billion

National Mitigation Commitments

All five Partner States have updated NDCs with 2030 reduction targets of roughly 20–38% below BAU, largely conditional on international support. Strategies converge on four pillars: (i) AFOLU (forest protection, restoration, agroforestry), (ii) clean energy and clean cooking, (iii) waste-to-resource systems, and (iv) low-carbon mobility. Cumulative finance needs exceed USD 120 billion (2020–2030), highlighting the importance of programmatic, results-based financing and robust MRV to unlock concessional and carbon-market flows (Republic of Kenya, 2020; United Republic of Tanzania, 2021; Republic of Uganda, 2022).

AFOLU: Nature-Based Mitigation at Scale

AFOLU is both the largest source and the largest opportunity. Priorities include avoiding deforestation, restoring degraded landscapes, expanding agroforestry, and improving livestock and soil management. Kenya's 10% tree-cover goal, Uganda's 21% forest-cover target, and Tanzania's community-based forest management exemplify scalable policy anchors. Programs such as Vi Agroforestry and Trees for Global Benefit show that smallholder systems can deliver measurable carbon and livelihood benefits when extension, market access, and tenure support align. Textbox 7-7 (Kenya Agricultural Carbon Project) distills lessons: soil-carbon projects can work, but farmer incentives, low transaction costs, and transparent benefit-sharing are decisive for durability.

Textbox 7-7: The Kenya Agricultural Carbon Project – Lessons for Climate-Smart Agriculture

The Kenya Agricultural Carbon Project (KACP), launched in 2009, was the first initiative in Africa to generate carbon credits from smallholder agriculture. Implemented by Vi Agroforestry in Bungoma, Kisumu, and Siaya counties near Lake Victoria, the project mobilized over 30,000 farmers (later 60,000) to adopt Sustainable Agricultural Land Management (SALM) practices such as agroforestry, composting, mulching, and reduced tillage. These practices improved soil organic carbon, water retention, and productivity, while also linking farmers to the voluntary carbon market (Tennigkeit & Wilkes, 2013; Vi Agroforestry, n.d.-a).

A landmark achievement came in 2014 when KACP issued the world's first soil carbon credits under a SALM methodology, certified by the Verified Carbon Standard (Verra, 2014). Reports highlighted increased yields of 15–20% and improved food security, with many households moving from one to three meals per day (World Bank, 2014; Vi Agroforestry, n.d.-b). The project also strengthened farmer groups, built local capacity, and demonstrated how climate-smart agriculture can deliver adaptation and mitigation benefits.

However, critical evaluations questioned its climate and economic claims. Methodological compromises, including heavy uncertainty discounts, limited revenue from carbon credits, while high transaction costs further reduced farmer benefits (Broberg, 2015; Institute for Agriculture and Trade Policy, 2012). Payments were often too small to incentivize adoption, and farmers lacked ownership or transparency in credit valuation (Wachiye et al., 2019).

The KACP underscores that livelihood improvements—not carbon finance—must remain the central value proposition for smallholders. Success requires equitable partnerships, realistic financial models, and strong local institutions to ensure benefits are tangible, transparent, and sustainable.

Energy, Waste, and Transport Transitions

Mitigation in energy hinges on renewables scale-up (solar, hydro, wind, geothermal), grid and end-use efficiency, and clean-cooking access to reduce biomass dependence and forest pressure. Utility efficiency efforts (e.g., Watergy) demonstrate how operational savings translate into direct emission cuts. Urban mitigation rests on a circular-economy approach: landfill-gas capture/biogas, organics diversion to compost/AD, and wastewater treatment with energy recovery, complementing basin initiatives like Lakewide Inclusive Sanitation (LWIS) that pair public-health gains with CH_4 reductions. In transport, lake-based logistics and green-port modernization can displace high-emitting road freight; pairing this with electrified/efficient last-mile solutions maximizes system-wide abatement. Selected programs and pipeline projects are summarized in Table 7-9.

Table 7-9. Summary Table of Mitigation Programs and Projects

Country/ Region	Project/Program Name	Budget (USD)	Duration	Key Objectives	Coverage
Regional	Lake Victoria Basin Integrated Water Resources Management Programme (LVB IWRMP)	Not specified	Ongoing	Watershed restoration, reforestation, sustainable land management	All 5 LVB countries
Regional	Nile Cooperation for Climate Resilience (NCCR)	Not specified	Ongoing	Afforestation, watershed protection	7 Nile countries incl. LVB
Regional	LVEMP II	~210 million	2009–2017	Reduce environmental degradation, restore wetlands	All 5 LVB countries
Regional	LVB Resource Efficiency & Cleaner Production (LVB-RECP)	~4.4 million	2017–2019	Industrial efficiency, low-carbon production	All 5 LVB countries
Regional	Multinational Lake Victoria Maritime Comms. & Transport (MLVMCT)	73.6 million	Ongoing	Maritime transport efficiency, vessel modernization	Kenya, Uganda, Tanzania
Burundi	Bujumbura Climate Resilience Project	10 million	5 years (from 2024)	Restore degraded land, agroforestry	Bujumbura region
Burundi	Transport Resilience Project	120 million	Not specified	Transport efficiency, emission reductions	Key transport corridors
Kenya	KEWASIP	200 million	Ongoing	Landscape restoration, agroforestry, job creation	12 counties incl. LVB
Kenya	Kenya Agricultural Carbon Project (KACP)	~5 million (carbon credits)	2010–2030	Soil carbon sequestration, agroforestry	Western Kenya smallholder farms
Rwanda	Nyungwe-Ruhango Corridor Restoration	9 million	Ongoing	Forest & wetland rehab, green jobs	Ruhango, Nyanza, Nyamagabe
Uganda	Trees for Global Benefit (TGB)	~2 million (carbon credits earned)	2003–present	Tree planting, carbon offsets, livelihoods	Multiple districts incl. Mt. Elgon (LVB)
Uganda	National Carbon Market Regulations	Not specified	2025–ongoing	Framework for carbon projects & credits	Nationwide incl. LVB

Implementation Gaps and Scaling Enablers

Persistent bottlenecks include fragmented coordination, under-resourced MRV, and uneven project distribution. Priority enablers are: (1) harmonized basin-wide carbon accounting led by LVBC to aggregate outcomes and steer investments; (2) results-based finance and high-integrity carbon standards for peatland rewetting, forest restoration, and waste methane abatement; (3) targeted technical assistance for clean cooking and municipal services; and (4) risk-sharing instruments to crowd-in private capital for renewable energy, circular waste, and low-carbon logistics.

7.7 Private Sector Engagement in Climate Action within the Lake Victoria Basin

Historically, climate action in the region has been the purview of public sector entities and development partners. However, the sheer scale of the adaptation finance gap—estimated to be in billions of dollars annually—necessitates a paradigm shift (UNEP, 2025). Public funds alone are insufficient. The private sector, therefore, is no longer a peripheral actor but a central protagonist in the region's climate strategy. The engagement of businesses, ranging from multinational corporations to Small and Medium Enterprises (SMEs), is shifting from voluntary Corporate Social Responsibility (CSR) to strategic adaptation and mitigation mandates essential for survival and competitiveness. This section provides an analysis of the private sector's role in climate action within the LVB.

7.7.1 Industrial Efficiency and Mitigation through Resource Efficient and Cleaner Production (RECP)

The industrial sector is a key driver of employment, manufacturing output, and value addition in the Lake Victoria Basin (LVB), yet it has historically been a major contributor to nutrient pollution, hazardous effluent discharge, solid waste accumulation, and energy-related greenhouse gas (GHG) emissions. Weak enforcement, aging infrastructure, and limited access to clean technologies have constrained progress toward sustainable industrialization. The introduction of Resource Efficient and Cleaner Production (RECP) represents the Basin's most systematic private-sector pathway for simultaneously addressing water pollution, resource inefficiency, and climate mitigation.

RECP Strategy and Uptake in the Basin

RECP applies preventive environmental management to production processes to improve efficiency, reduce waste, and lower environmental and health risks. In the LVB, RECP was scaled through the World Bank–funded **"Engaging the Private Sector for Green Growth"** project, implemented by the LVBC and National Cleaner Production Centres across five Partner States. By 2020, 136 in-plant assessments had been completed—well above the original target—and 91% of participating enterprises implemented at least one RECP measure, confirming strong private-sector responsiveness when economic benefits are clear (World Bank, 2020).

Sectoral Mitigation Outcomes

Across priority industrial value chains, RECP interventions delivered measurable improvements in water efficiency, pollutant load reduction, and GHG mitigation, while strengthening industrial competitiveness.

- In the **sugar industry**, highly water-intensive processing and high-strength effluent posed persistent risks to river and lake water quality. Introduction of advanced wastewater treatment and water recycling systems enabled near-closed-loop water use, cutting freshwater abstraction by approximately 40% and reducing treated effluent BOD to within regulatory standards. Complementary energy-efficiency measures generated verified reductions in GHG emissions, while conversion of process residues into bio-fertilizer supported circular

economy practices and lowered upstream fertilizer-related carbon footprints.

- In the tea sector, thermal and electrical energy demand associated with tea withering and drying created sustained pressure on both grid electricity and biomass supplies. RECP retrofits—including high-efficiency fans, variable speed drives, lighting optimization, and improved boiler combustion systems—significantly reduced electricity consumption and biomass intensity. These measures delivered direct CO_2 emission reductions while also relieving deforestation pressure in upper catchments that regulate basin hydrology.
- In the **fish processing industry**, previously high water use and organic waste discharge contributed directly to nutrient loading and nearshore water quality degradation. RECP interventions reduced specific water consumption by roughly one-third, while full valorization of organic by-products into fish meal and fish oil eliminated solid organic waste disposal entirely. This sharply reduced untreated organic loading to the lake prior to final effluent treatment, contributing to mitigation of eutrophication and invasive aquatic weeds.

Aggregate Impact and Financing Constraints

By March 2020, industries in the LVB had mobilized US$20.96 million for RECP—about 70% of the target—and avoided 10,577 tCO_2e annually, with training and technology uptake exceeding expectations (World Bank, 2020). However, while low-cost efficiency measures are rapidly adopted, progress on capital-intensive upgrades (e.g., advanced wastewater treatment, boiler upgrades, and fuel switching) remained constrained by limited access to concessional finance and risk-sharing instruments for SMEs.

7.7.2 Climate-Smart Agriculture (CSA) and Value Chain Resilience

Agriculture underpins livelihoods and employment across the Lake Victoria Basin (LVB) but is also the sector most exposed to climate variability and extremes. Private agribusinesses, cooperatives, and commodity boards are progressively adopting Climate-Smart Agriculture (CSA) to protect supply chains, stabilize farmer incomes, and sustain export competitiveness under rising climate risk.

- **Tea Value Chain:** The Kenya Tea Development Agency (KTDA)—representing over 560,000 smallholders—has embedded climate adaptation and mitigation directly into tea value-chain management in response to frost, hail, and rainfall variability disrupting green-leaf supply. Key measures include run-of-river small hydropower plants to secure low-carbon energy for tea processing and reduce exposure to drought-induced grid shortages. Complementary afforestation and woodlot programmes (Figure 7-13) provide sustainable biomass for tea drying while stabilizing soils and local microclimates. To manage long-term production risk, KTDA also promotes crop diversification and integrated dairy farming as buffers against climate-driven yield losses (CDKN, 2013).
- **Coffee Sector:** In Uganda, rising temperatures and pest pressure threaten both Robusta and Arabica production. The Climate-Smart Coffee pathway coordinated by the Uganda Coffee Development Authority with private exporters applies climate zoning and altitude-gradient analysis to guide future investment and extension priorities (IISD, 2014). Adaptation is anchored in agroforestry-based shade management, which reduces heat stress, improves soil moisture retention, and enhances on-farm carbon sequestration. These practices are increasingly linked to certification schemes that translate climate resilience into price premiums. Exporters also invest strategically in private extension services, promoting mulching, water conservation, and improved drought-tolerant planting material to safeguard long-term supply volumes (IISD, 2014; TNC, 2015).



Figure 7-13. *A tea plantation in Kericho, Kenya with a woodlot in the background (Source: Afircalanders).*

- **Fisheries and Aquaculture:** Capture fisheries—especially the Dagaa/Omena value chain—are highly sensitive to rainfall variability, which disrupts traditional sun-drying and drives post-harvest losses. Private firms are introducing solar-powered drying technologies, cutting drying time from days to hours and sharply reducing spoilage, thereby stabilizing fisher incomes (LVFO, 2025). Climate resilience is further strengthened through the transition from kerosene to solar fishing lamps, which lowers operating costs, reduces emissions, and eliminates fuel-spill pollution risks. At the production level, private investment in cage aquaculture and land-based aquaponics—including zoned cage systems—diversifies supply away from climate-stressed wild stocks while containing localized environmental impacts (LVFO, 2025).

7.7.3 Financial Mechanisms: Mobilizing Capital for Climate Resilience

Scaling climate adaptation and mitigation in the Lake Victoria Basin (LVB) depends on financial instruments that can de-risk investment, crowd in private capital, and translate climate exposure into bankable opportunity. Regional financial markets are increasingly responding through green bonds, climate credit facilities, parametric insurance, and ecosystem payment mechanisms.

Green Bonds and Climate Finance Facilities

The emergence of green bonds and targeted climate credit lines signals growing market maturity for climate finance in East Africa. A landmark example is Tanzania's Tanga Water Green Bond, through which the Tanga Urban Water Supply and Sanitation Authority raised US$20.8 million to finance climate-resilient water

infrastructure—demonstrating the viability of sub-national access to private capital markets.

At the regional level, the Trade and Development Bank (TDB) has introduced Green Shares and, in partnership with the European Investment Bank (EIB), established a US$120 million SME and climate action facility, with a dedicated climate allocation. Commercial banks are deepening this momentum: Equity Bank's €100 million EIB credit line supports climate-smart agriculture and clean energy, while Standard Bank's net-zero lending strategy is accelerating green loan structuring for renewable energy and sustainable infrastructure (EIB, 2019; EIB, 2021; Standard Bank Group, 2022).

Parametric Insurance: Transferring Climate Risk

Conventional indemnity insurance remains inaccessible for most smallholders due to high transaction and verification costs. Parametric (index-based) insurance, driven by private innovation, has transformed climate risk transfer by linking payouts directly to satellite-derived weather and yield indices.

ACRE Africa insures farmers using mobile-enabled weather and picture-based verification, with automated mobile money payouts once climate thresholds are breached. By 2021, the scheme had reached over 1.7 million farmers and mobilized more than US$180 million in coverage (CPI, 2021). Pula Advisors applies area-yield index insurance integrated with digital platforms such as Safaricom's DigiFarm, protecting over US$1 billion in agricultural value. These mechanisms shift climate risk from farmers to global reinsurance markets, enabling productive investment in higher-value inputs.

Payment for Ecosystem Services (PES)

The Upper Tana–Nairobi Water Fund offers a proven Payment for Ecosystem Services (PES) model with direct relevance to the LVB. Downstream corporations—including KenGen, Coca-Cola, and East African Breweries—finance upstream soil and water conservation through a dedicated fund. This reduces sedimentation, stabilizes hydropower generation, and lowers long-term infrastructure maintenance costs (TNC, 2015). The model demonstrates how private capital can be systematically aligned with watershed-scale climate adaptation and water security.

7.7.4 Infrastructure and Urban Resilience: The Role of the Private Sector

Rapid urban growth in the Lake Victoria Basin (LVB)—notably in Kampala, Kisumu, and Mwanza—is intensifying pressure on transport systems, sanitation services, and lakeshore ecosystems. The private sector is increasingly central to delivering low-carbon infrastructure, resilient urban services, and pollution control.

- **Green Ports and Low-Carbon Transport:** The modernization of Kisumu and Mwanza ports is repositioning inland water transport as a lower-carbon alternative to road freight. At Kisumu, port upgrades are strengthening environmental compliance and cold-chain logistics, reducing post-harvest losses and transport emissions (World Port Sustainability Program, 2024). In Mwanza, the EU-supported Green and Smart Cities Programme is leveraging private investment in waste management and circular economy solutions, directly reducing pollution loads entering the lake (EU External Action, 2025).
- **Urban Sanitation and Pollution Control:** Under the Lakewide Inclusive Sanitation Strategy, the private sector plays a growing role in urban waste management (World Bank, 2022). In Kampala, private cesspool operators working with the National Water and Sewerage Corporation are improving fecal sludge collection from informal settlements, while emerging enterprises convert sludge into fuel briquettes, creating a market-based pollution control pathway. In Kisumu, private developers and microfinance institutions are expanding flood-resilient housing solutions in high-risk settlements such as Nyalenda, strengthening household-level climate resilience (World Bank, 2022).



Figure 7-14. *The rehabilitated Kisumu Port, Kenya. Rehabilitation has reduced the ports carbon footprint. (Source: Kenya Ports Authority).*

7.7.5 Sustainable Tourism

Tourism in the LVB and its catchment areas relies entirely on the preservation of natural capital. The private sector is a primary guardian of biodiversity.

- **Ecotourism Models:** In the Bwindi Impenetrable Forest (a critical water tower for the region), private eco-lodges invest heavily in community development and conservation. By sharing revenues with local communities and sourcing food locally, they create an economic incentive for conservation, reducing poaching and deforestation (SOMO, 2024).
- **Carbon Offsetting:** Tour operators like Msafiri Tours in Uganda have introduced "CO2 Offset Travel," where tourists fund tree planting and clean cookstove projects in local communities. This voluntary mechanism channels tourism revenue directly into community-based mitigation and adaptation projects.

7.7.6 Barriers to Scaling Private Sector Engagement

Despite growing momentum, several structural barriers continue to constrain the scale and pace of private investment in climate resilience in the Lake Victoria Basin.

First, weak project bankability and limited preparation capacity among municipalities and SMEs restrict access to commercial finance, as many proposals fail to meet investor risk-return requirements (CDP, 2018). Second, regulatory disharmony across Partner States—including inconsistent tax incentives for green technologies and unclear rules for independent power producers—creates uncertainty and raises transaction costs (EAC, 2022). Third, the expansion of parametric insurance remains constrained by sparse weather-station networks and persistent basis risk, which weakens farmer confidence in index-based products (CPI, 2021). Finally, information asymmetry and financial literacy gaps limit SME awareness of RECP opportunities and green credit facilities, slowing fund absorption despite available capital (EAC, 2022).

7.7.7 Future Pathways: Expanding the Private Sector's Role

To unlock its full contribution to basin-wide climate resilience, the private sector must move beyond pilots toward systemic scale.

- **Scaling Nature-Based Solutions through Blended Finance:** Replicable water fund models—such as the Upper Tana–Nairobi Water Fund—should be extended to priority sub-catchments including the Mara and Kagera Rivers. Anchor investments by large water users, combined with guarantees and first-loss capital from development partners, can attract commercial finance into watershed restoration.
- **Climate-Resilient Supply Chain Certification:** Large agribusinesses can drive climate resilience by embedding climate-resilient standards into contract farming systems. By bundling drought-tolerant seeds, drip irrigation, and soil diagnostics into producer contracts, aggregators simultaneously secure future supply and strengthen out-grower resilience.
- **Data-Driven Climate Services (Climate FinTech):** Strong market potential exists for digital climate services, including hyper-local weather forecasts, pest alerts, and tailored agronomic advice delivered via mobile platforms. Private tech firms—working with telecom operators—are best positioned to commercialize climate data services at scale.
- **Circular Economy Industrial Parks:** Future industrial zones near Kampala, Entebbe, Jinja, Kisumu, Mwanza and Kigali (Figure 7-15) should adopt eco-industrial park designs, enabling shared water recycling, waste-heat recovery, and industrial symbiosis. This would lower production costs while minimizing cumulative environmental footprints.



Figure 7-15. *An aerial view of Kigali Special Economic Zone. Well-planned industrial zones are a key to sustainable development and climate resilience (Source: The New Times, Rwanda).*

7.8 Recommendations and Strategic Priorities

A Turning Point for Regional Climate Action

The Lake Victoria Basin (LVB) stands at a critical juncture. The evidence presented in this chapter highlights both the fragility of current climate resilience and the opportunity to position the Basin as a continental model for integrated climate action. Partner States have made strong commitments through their Nationally Determined Contributions (NDCs) and implemented successful projects, but efforts remain fragmented and underfinanced. Recent experience further demonstrates that public funding alone is insufficient to meet the scale of adaptation and mitigation needs, underscoring the growing importance of private-sector investment, blended finance, and market-based climate solutions. Advancing basin-wide resilience therefore requires coordinated governance, innovative financing, and large-scale implementation under the leadership of the Lake Victoria Basin Commission (LVBC). Table 7-10 summarizes the key recommended actions to enhance climate change adaptation and mitigation in the lake basin.

Table 7-10. Recommended Climate Action Measures in the Lake Victoria Basin

National-Level Interventions (Coordinated by National Governments)	Regional-Level Interventions (Coordinated by the EAC Secretariat and LVBC)
1. Strengthen Climate Governance and Institutional Coordination 1.1. Integrate climate risk across national and subnational development planning, linking local action to basin and regional frameworks. 1.2. Strengthen national institutions and legislation to align with regional protocols and ensure enforcement at subnational levels.	**1. Strengthen Climate Governance and Institutional Coordination** 1.3. Empower LVBC to lead basin-wide coordination, harmonize climate policies, and facilitate joint programming and monitoring. 1.4. Enhance accountability through ratification and enforcement of regional environmental and climate protocols.
2. Expand Climate Finance and Resource Mobilization 2.1. Diversify national climate financing through domestic allocations, green bonds, microfinance, and PPPs. 2.2. Ensure equitable access to finance for women, youth, and smallholders through concessional credit and risk-sharing facilities, including support for climate-smart SMEs and agribusiness.	**2. Expand Climate Finance and Resource Mobilization** 2.3. Develop a Basin Climate Investment Plan aligned with national NDCs and the LVBC IWRM Strategy. 2.4. Mobilize regional and international funding through climate funds and blended-finance platforms for transboundary investments.
3. Strengthen Data, Knowledge, and Early Warning Systems 3.1. Invest in national-level climate services, hydrological monitoring, and data infrastructure. 3.2. Integrate Indigenous and Local Knowledge into national adaptation programs to ensure locally relevant solutions.	**3. Strengthen Data, Knowledge, and Early Warning Systems** 3.3. Establish interoperable regional monitoring networks and shared data portals for water, ecosystems, and climate. 3.4. Expand basin-wide early warning systems (e.g., HIGHWAY) to cover floods, droughts, and climate-linked health risks. 3.5. Coordinate regional climate research and knowledge exchange.

National-Level Interventions (Coordinated by National Governments)	Regional-Level Interventions (Coordinated by the EAC Secretariat and LVBC)
4. Scale Ecosystem-Based Adaptation 4.1. Mainstream ecosystem-based approaches—wetland restoration, reforestation, and climate-smart agriculture—into national programs. 4.2. Protect and restore peatlands, forests, and wetlands as national priorities for mitigation and resilience. 4.3. Increase investment in blended grey and green infrastructure for flood and drought management. 4.4. Enhance Groundwater Recharge and Protection: Develop and enforce integrated groundwater management policies linking land-use planning, wetland conservation, and climate adaptation; implement recharge structures (check dams, percolation tanks, recharge wells) in priority zones; restore degraded catchments and wetlands; establish protected recharge zones around critical aquifers such as Kagera; and promote rainwater harvesting and soil conservation at household and community levels	**4. Scale Ecosystem-Based Adaptation** 4.5. Coordinate cross-border ecosystem restoration and management of transboundary wetlands, forests, and protected areas. 4.6. Develop regional guidelines and standards for nature-based and climate-resilient infrastructure. 4.7. Strengthen Regional Coordination for Groundwater Recharge under Climate Change: Establish transboundary aquifer management frameworks (e.g., Kagera Aquifer) with shared monitoring and data exchange; develop regional guidelines for groundwater recharge and vulnerability mapping; coordinate basin-wide research on groundwater–climate interactions; mobilize regional climate finance for recharge infrastructure and landscape restoration; and integrate recharge targets into the Basin-wide Climate Change Adaptation Strategy and LVBC IWRM programs
5. Accelerate Mitigation and Low-Carbon Transition 5.1. Prioritize AFOLU (afforestation, agroforestry, sustainable livestock) as key mitigation pathways. 5.1. Expand renewable-energy generation (solar, wind, geothermal, hydropower with safeguards) and promote energy efficiency, including in industry through RECP-type approaches. 5.2. Advance green transport and circular-economy initiatives—waste-to-energy, composting, and methane capture—to reduce urban emissions.	**5. Accelerate Mitigation and Low-Carbon Transition** 5.3. Support regional power interconnections and low-carbon transport corridors, including inland-waterway freight on Lake Victoria. 5.4. Harmonize regional emission-reduction and energy-efficiency standards.
6. Build Social Resilience and Equity 6.1. Invest in climate education, vocational training, and green-job creation targeting youth and women. 6.2. Strengthen social-protection and livelihood-diversification mechanisms for vulnerable populations. 6.3. Integrate climate migration and displacement planning into national development frameworks.	**6. Build Social Resilience and Equity** 6.4. Develop basin-wide frameworks for gender-responsive and inclusive climate action. 6.5. Facilitate regional capacity-building, peer learning, and awareness campaigns.

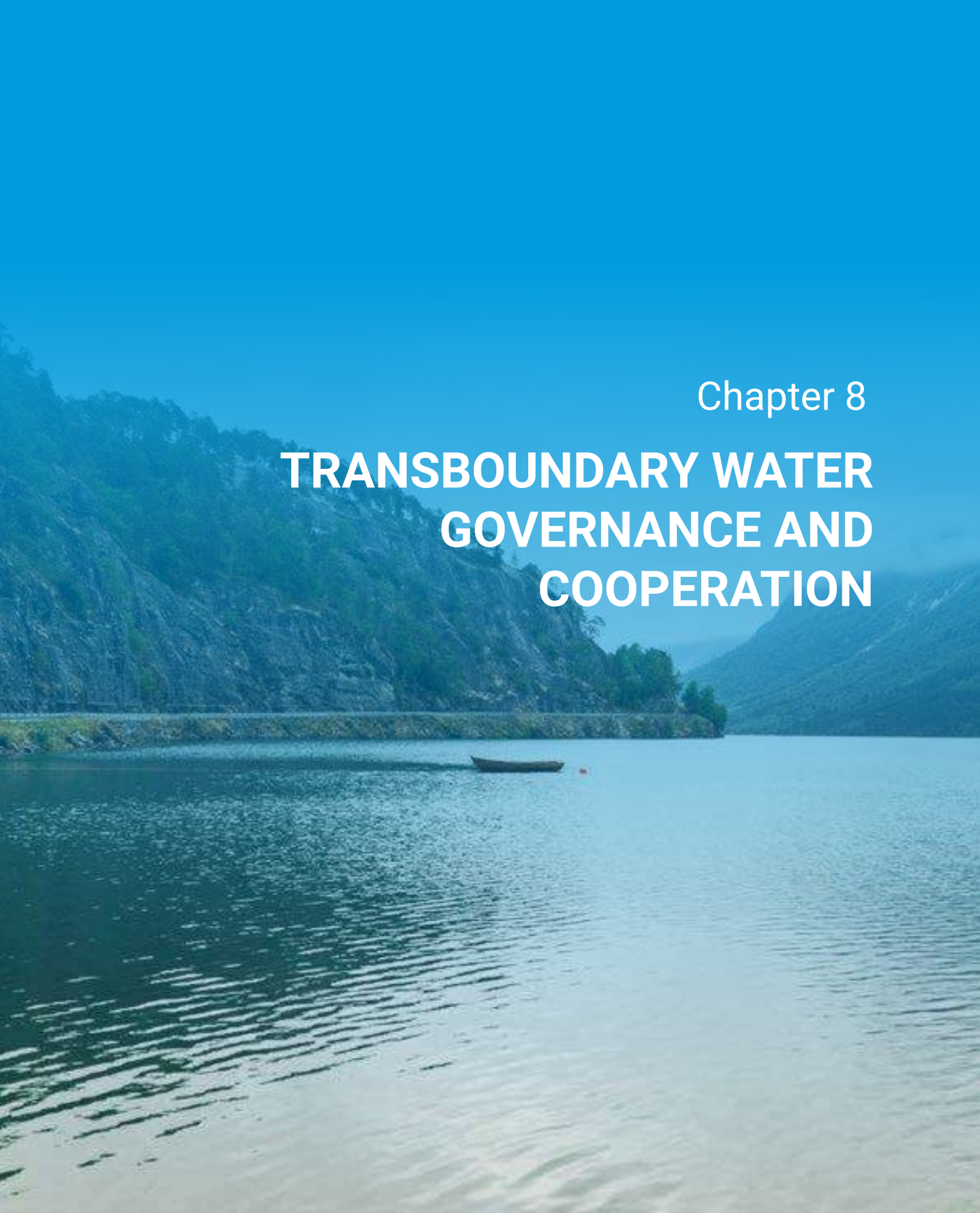
National-Level Interventions (Coordinated by National Governments)	Regional-Level Interventions (Coordinated by the EAC Secretariat and LVBC)
7. Deepen Regional and Global Partnerships 7.1. Engage with global and bilateral partners to support national climate priorities and NDC implementation.	**7. Deepen Regional and Global Partnerships** 7.2. Strengthen collaboration with NELSAP, LVFO, IGAD, and COMESA to align WEFE nexus investments. 7.3. Link LVB priorities with Agenda 2063, the SDGs, and the Paris Agreement to attract visibility and finance. 7.4. Promote innovation partnerships with regional research institutions, academia, and the private sector.

Conclusion

Implementing these priorities would shift the Lake Victoria Basin from fragmented projects toward a more coordinated and sustainable climate agenda that also leverages private investment, climate-smart value chains, and market-based financing instruments. With strong political commitment, sustained investment, and effective regional leadership, the Basin can safeguard livelihoods, restore ecosystems, and emerge as a continental leader in integrated climate resilience and low-carbon development.

Section IV

Governance, Synthesis and Strategic Outlook



Chapter 8

TRANSBOUNDARY WATER GOVERNANCE AND COOPERATION

SUMMARY (CHAPTER 8)

Chapter 8 analyses the transboundary governance systems that underpin sustainable management of the Lake Victoria Basin (LVB) within the dual frameworks of the East African Community (EAC) and the wider Nile Basin. It traces the historical and legal evolution of cooperation and examines the implications of the entry into force of the Nile River Basin Cooperative Framework Agreement (CFA) in 2024 and the emerging Nile River Basin Commission (NRBC). Using the framework–function dichotomy, the chapter demonstrates that persistent environmental degradation reflects not weak policies, but implementation, capacity, coordination, and financing gaps. It evaluates institutional performance, flagship regional programmes, stakeholder participation, private sector engagement, and basin-wide knowledge systems. The chapter concludes that the future of LVB governance depends on shifting from framework to function through predictable financing, strengthened institutions, enforceable accountability, and strategic alignment within the evolving Nile governance architecture.



Legal and Institutional Frameworks

The entry into force of the Nile River Basin Cooperative Framework Agreement (CFA) constitutes a major shift in the basin's legal architecture



Institutional Capacity, Coordination, and Political Economy

Significant asymmetries in national institutional capacity and political prioritization continue to shape cooperation outcomes,



Knowledge Systems, Monitoring, and Decision Support

Basin-wide monitoring and data-sharing systems remain structurally weak, with fragmented hydrometeorological networks, limited groundwater and ecosystem data, and inadequate integration of scientific research into policy and operational decision-making.



Strategic and Geopolitical Context

The Lake Victoria Basin represents one of Africa's most strategically significant transboundary water systems

The hydrological and geopolitical linkage between Lake Victoria and the wider Nile system elevates the basin beyond a sub-regional water body

Key Messages

Strategic and Geopolitical Context

1. **The Lake Victoria Basin represents one of Africa's most strategically significant transboundary water systems,** underpinning regional integration, economic development, and political stability across five riparian states within the overlapping governance spheres of the East African Community (EAC) and the Nile Basin Initiative (NBI).
2. **The hydrological and geopolitical linkage between Lake Victoria and the wider Nile system elevates the basin beyond a sub-regional water body**, embedding it within broader upstream–downstream dynamics, regional security considerations, and continental water diplomacy.

Legal and Institutional Frameworks

3. **The entry into force of the Nile River Basin Cooperative Framework Agreement (CFA) constitutes a major shift in the basin's legal architecture**, reinforcing principles of equitable utilization, benefit sharing, and cooperation. However, its practical implications for day-to-day Lake Victoria governance remain only partially operationalized.
4. **The Lake Victoria Basin Commission (LVBC) has consolidated its role as the principal regional coordination body,** but its effectiveness continues to be constrained by limited enforcement authority, overlapping institutional mandates, and dependence on project-based donor financing.
5. **The "framework–function" dichotomy defines Basin governance.** While the transboundary water governance system in the LVB is institutionally robust, practical outcomes are constrained by political, financial, and technical limitations. The challenge is not institutional absence but functional misalignment between policy ambition and operational capacity.

Institutional Capacity, Coordination, and Political Economy

6. **Significant asymmetries in national institutional capacity and political prioritization continue to shape cooperation outcomes,** complicating harmonization of policies, enforcement of standards, and synchronized investment planning across the basin.
7. **Tensions between national sovereignty and regional collective action persist,** influencing data sharing, regulatory enforcement, and the delegation of authority to regional bodies.
8. **Four systemic weaknesses persist.** These are: (a) policy–enforcement gaps due to limited authority and capacity; (b) financial unsustainability and donor dependence; (c) fragmented data systems; and (d) weak cross-sectoral coordination.

Development Results and Dividends of Cooperation

9. **Despite coordination and capacity constraints, transboundary cooperation has delivered measurable dividends,** including enhanced political trust, reduced conflict risks, strengthened fisheries and environmental management, improved water supply and sanitation services, and expanding regional navigation and infrastructure initiatives. Beyond the water, benefits in economic integration, environmental protection, and social co-benefits are increasingly evident, confirming the strategic value of sustained cooperative action even under imperfect governance conditions.
10. Although flagship initiatives—LVEMP, LVWATSAN, and the LVB-IWRM Programme—have delivered measurable results **(**related to improved sanitation, cleaner production, and institutional capacity), **their impacts remain localized due to lack of scale-up and mainstreaming in national budgets.**

Stakeholder Participation and Private Sector Engagement

11. **Stakeholder participation has expanded** to involve local governments, civil society, water user associations, beach management units, and private sector actors **but engagement remains uneven and weakly institutionalized,** with most participation still driven by externally financed projects rather than embedded, permanent governance mechanisms.
12. **Private sector engagement is emerging as an important but still under-leveraged pillar,** particularly in water services, navigation, fisheries value chains, and pollution control, constrained by bankability challenges and regulatory uncertainty.

Knowledge Systems, Monitoring, and Decision Support

13. **Basin-wide monitoring and data-sharing systems remain structurally weak,** with fragmented hydrometeorological networks, limited groundwater and ecosystem data, and inadequate integration of scientific research into policy and operational decision-making.

14. **Persistent data silos and uneven national reporting continue to undermine evidence-based governance,** early warning systems, and climate-risk-informed planning across the basin.

Financial Sustainability and Long-Term Resilience

15. **Financial sustainability constitutes the most binding structural constraint on effective transboundary governance,** with core regional functions—monitoring, laboratories, coordination, and compliance—heavily dependent on short-term donor projects.

16. **The absence of stable, predictable domestic financing mechanisms weakens institutional continuity,** undermines long-term planning, and exposes basin management to cyclical funding volatility.

Strategic Outlook: From Framework to Function

17. **The future effectiveness of Lake Victoria Basin governance depends on a decisive shift from "framework to function."** This requires:

    a. Strengthening LVBC's technical, coordination, and reporting mandate;
    b. Embedding joint monitoring and compliance functions into national budgets;
    c. Finalizing and enforcing basin-wide data-sharing and information protocols;
    d. Expanding water diplomacy, institutional capacity development, and trust-building;
    e. Establishing innovative and predictable financing instruments to sustain cooperation beyond project cycles.



Figure 8-1. *The new offices of the Lake Victoria Basin Commission Secretariat in Kisumu, Kenya.*

Key State Indicators – Transboundary Cooperation (2025)

Strategic & Thematic Areas	Indicator / Metric	Value / Range (2025)
T1 Enabling environment		
T1.1 Transboundary policies, agreements, and conflict resolution	Status of legal and institutional frameworks	Strong and well-established framework of multilateral treaties, bilateral agreements, MoUs, and regional and national institutions supporting cooperation and peaceful dispute resolution
T1.2 Data and information exchange	Basin-wide information platforms	LVB-WIS and related platforms established
	Operational status of data exchange	Not yet fully operational
	Real-time information sharing	Limited; constrained by weak implementation of data-sharing frameworks
T1.3 Capacity building	Regional and national capacity gaps	Significant gaps in human resources, technical tools, and financing
	Status of capacity-building programmes	Programmes exist but remain weak relative to needs
T2 Transboundary projects		
T2.1 Transboundary IWRMD projects	Scope of transboundary projects	Projects implemented across water quality monitoring, wastewater treatment, water supply, and climate adaptation
	Effectiveness of implementation	Mixed results; varying levels of success

8.1 Introduction

8.1.1 Strategic Context of the Lake Victoria Basin

The Lake Victoria Basin (LVB) is a cornerstone of East Africa's environmental security, economic development, and regional integration. Covering approximately 193,000 km² across Burundi, Kenya, Rwanda, Tanzania, and Uganda, the basin sustains over 45 million people through fisheries, agriculture, hydropower, transport, and domestic water supply. Lake Victoria itself—Africa's largest freshwater lake at 68,800 km² and the world's second largest—acts as a regional hydrological "water tower," moderating climate, sustaining wetlands and rivers, and underpinning rain-fed agriculture that employs the majority of the basin's population. The East African Community (EAC) has formally designated the basin as a ***Regional Economic Growth Zone*** and Area of ***Common Economic Interest***, underscoring its strategic importance for economic integration, stability, and shared prosperity.

However, this exceptional regional value is increasingly compromised by intense, competing sectoral pressures—including expanding agriculture, rapid urbanization, hydropower, and a fishery valued at USD 1.12 billion—which are driving accelerating ecological stress. Widespread pollution from municipal, industrial, and agricultural sources has intensified eutrophication and fueled the proliferation of invasive species, posing direct risks to food security and public health. Crucially, these challenges are intrinsically transboundary and amplified by climate variability; upstream land-use changes and dam operations create cascading impacts on downstream water quality and flow regimes. This deep interdependence binds the riparian states into a regional "community of interest" that extends beyond the lake itself into the wider Nile system, linking the basin directly to the broader hydro-politics of the Nile (Petersen-Perlman et al., 2017; Hassan, 2023). The interdependence renders purely national management approaches structurally inadequate, making sustained regional cooperation indispensable.

In light of this imperative for cooperation, this chapter examines Lake Victoria Basin governance through a dual lens. Internally, it assesses how regional institutions—particularly the Lake Victoria Basin Commission (LVBC)—perform their mandates for coordination, policy harmonization, and environmental regulation. Externally, it situates the LVB within the evolving Nile Basin architecture, including the Nile Basin Initiative (NBI) and the newly established Nile River Basin Commission (NRBC). This dual perspective is especially critical following the entry into force of the Nile River Basin Cooperative Framework Agreement (CFA) in October 2024, which reshapes both the legal and political context of transboundary water governance and redefines how the Lake Victoria Basin positions itself within Nile-wide cooperation frameworks.

8.1.2 Defining Transboundary Water Governance

For the purposes of this report, water governance is understood not merely as the actions of governments but as the entire system of policies, laws, institutions, and processes—both formal and informal—that guide decision-making and resource management. This holistic definition encompasses the roles of regional bodies like the Lake Victoria Basin Commission (LVBC) and Nile Basin Initiative, national ministries and environmental agencies, and local community-based organizations such as Water Resource User Associations (WRUAs) and Beach Management Units (BMUs).

The governance framework operates at multiple nested scales—regional, national, and local—with distinct but interconnected responsibilities. At the regional level, cooperative agreements and institutions coordinate transboundary management. At the national level, governments establish legal frameworks and enforcement mechanisms. At the local level, communities and civil society organizations implement on-the-ground interventions. Understanding this multi-layered architecture requires distinguishing between de jure (on-paper) frameworks and de facto (in-practice) implementation—a distinction critical to diagnosing the basin's governance challenges.

8.1.3 The Framework-Function Dichotomy

This chapter introduces a central analytical concept: the **framework-function dichotomy**. The LVB Partner States have successfully constructed one of the most sophisticated architectures for transboundary water cooperation on the African continent. The region boasts world-class legal protocols, harmonized regional standards, and permanent institutional arrangements codified in international treaties.

Yet despite these impressive achievements, the basin continues to face severe and accelerating environmental degradation. Water quality has deteriorated markedly, with eutrophication driving fish kills and threatening the lake's fishery. Invasive species repeatedly surge despite earlier control successes. This paradox reflects systemic gaps between institutional design and practical implementation, shaped by differing national priorities, resource constraints, and varying capacities among Partner States.

Understanding this framework-function dichotomy is crucial for two reasons. First, it explains why well-designed interventions have not achieved basin-wide impact—the problem is not inadequate policy but insufficient implementation capacity. Second, it guides future strategies by highlighting that progress requires not new frameworks but rather the operational empowerment, resource mobilization, and political commitment needed to activate existing ones.

8.1.4 Chapter Objectives and Structure

This chapter critically assesses the Lake Victoria Basin's multi-layered water governance framework, synthesizing evidence from across the State of Basin Report to evaluate progress, identify persistent systemic gaps, and chart pathways toward more effective cooperation.

The chapter is organized into eight major parts covering the conceptual framework for analysis; the historical foundations for cooperation; the governance architecture; the situation of the LVB within the broader Nile Basin context; evaluation of implementation performance; examination of governance mechanisms; and cross-cutting challenges. The chapter concludes with actionable recommendations for Partner States, LVBC, and development partners.

Overall, it moves from description (what exists) to analysis (why gaps persist) to prescription (how to achieve progress), using the framework–function dichotomy as its guiding lens.

> "Covering approximately 193,000 km² across Burundi, Kenya, Rwanda, Tanzania, and Uganda, the basin sustains over 45 million people through fisheries, agriculture, hydropower, transport, and domestic water supply."

8.2 Historical, Legal and Geopolitical Foundations of Cooperation

8.2.1 Historical and Cultural Enablers

The foundations of cooperation in the Lake Victoria Basin are deeply rooted in shared history, culture, and institutional continuity, which collectively created a strong basis for regional integration and trust-building among Partner States.

- **Shared Heritage and Identity:** The 1999 EAC Treaty acknowledges the Partner States' long-standing historical, commercial, and cultural ties. A shared regional identity—often termed ***Eastafricanness***—and the widespread use of Kiswahili as a common language have fostered mutual trust and lowered political barriers to cooperation.
- **Colonial Legacy and Institutional Continuity**: A shared colonial administrative system under British East Africa (Cambridge University Press, 2017) endowed most Partner States with common legal and bureaucratic traditions. These similarities simplified post-independence policy harmonization, such as in water-quality regulation and public-sector coordination.
- **Precedent for Regional Integration**: Historical institutions—the Kenya-Uganda Railway (1901), the Customs Union (1917), and later the East African High Commission and the first East African Community (1967–1977)—provided early experience in joint governance. Though the first EAC collapsed in 1977 amid ideological rifts, its legacy and institutional memory paved the way for renewed cooperation through the 1993 Tripartite Commission and the 1999 EAC Treaty.

8.2.2 Water Hyacinth as a Catalyst for Modern Cooperation

After the collapse of the first EAC in 1977, political trust among Partner States was low. A new, non-political catalyst emerged in the 1990s: the devastating water hyacinth (***Eichhornia crassipes***) infestation. At its peak, the weed covered tens of thousands of hectares, blocking fisheries, water intakes, transport routes, and hydropower facilities (Chapter 3). The crisis affected all riparian countries simultaneously, demanding a coordinated regional response.

The first Lake Victoria Environmental Management Project (LVEMP I) successfully applied integrated pest management using ***Neochetina*** weevils, reducing infestation by over 95 % between 1998 and 2001 (Chapter 3). This achievement demonstrated that joint technical action could deliver tangible basin-wide benefits (Petersen-Perlman et al., 2017).

Beyond its ecological success, the response rebuilt political confidence and proved that shared challenges could be effectively addressed through cooperation. It provided the foundation for renewed integration under the 1999 EAC Treaty and the 2003 Protocol for the Sustainable Development of the Lake Victoria Basin. The crisis thus transformed a regional disaster into a turning point for collective action and institutional trust.

8.2.3 From Colonial Constraints to Cooperative Frameworks

The current governance landscape cannot be understood without reference to colonial treaties that historically governed the Nile. The 1929 Exchange of Notes and the 1959 Nile Waters Agreement established a legal regime that granted downstream states (Egypt and Sudan) near-total control over the Nile River's flow and veto power over upstream infrastructure. For decades, this 'Nile question' retarded the development of formal frameworks within the Lake Victoria Basin, as upstream states were wary of agreements that might implicitly recognize these colonial constraints.

The paradigm shifted in the late 20th century

as upstream states, driven by population growth and economic needs, sought a more equitable framework. The renaissance of the EAC in 1999 and the concurrent launch of the Nile Basin Initiative (NBI) marked a transition from zero-sum contests toward benefit sharing and Integrated Water Resources Management (IWRM).

8.2.4 Regional Legal Frameworks

The EAC Treaty

The Treaty for the Establishment of the East African Community (EAC Treaty) serves as the overarching legal instrument governing intergovernmental cooperation within the East African region. Signed on 30 November 1999 and entering into force on 7 July 2000, the Treaty revitalized regional integration following the dissolution of the original community in 1977.

Initially established by the three founding members—Kenya, Uganda, and the United Republic of Tanzania—the Community has since expanded significantly. As of 2026, the EAC comprises eight Partner States: Burundi, the Democratic Republic of the Congo, Kenya, Rwanda, Somalia, South Sudan, Uganda, and Tanzania.

The EAC Treaty places a strong emphasis on the environment and natural resources, primarily under Chapter 19 (Articles 111–114). These provisions mandate that Partner States cooperate in the management of shared ecosystems to prevent environmental degradation and promote sustainable development.

Specific to the Lake Victoria Basin, the Treaty includes several vital commitments:

- **Article 114:** Explicitly identifies the sustainable management and utilization of natural resources as a priority, specifically calling for the establishment of a dedicated body for the management of Lake Victoria.
- **Catchment Management:** It directs Partner States to adopt common regulations for the conservation of catchment forests and the management of the terrestrial watershed to safeguard the basin's water quality and quantity.
- **Pollution Control:** Partner States agree to harmonize environmental policies and standards to mitigate the impacts of developmental activities on the lake's ecosystem.

Protocol for Sustainable Development of Lake Victoria Basin (2003) and LVBC Act (2022)

While the EAC Treaty provides the broad legal mandate, the Protocol for Sustainable Development of Lake Victoria Basin (2003) serves as the specific implementing instrument for the basin. Pursuant to Article 151 of the Treaty (which allows for the conclusion of sectoral protocols) and Article 114, this Protocol established the Lake Victoria Basin Commission (LVBC).

The Protocol is an integral part of the EAC Treaty; it provides the detailed legal and institutional framework for coordinating activities within the lake and its watershed and commits the Partner States to sustainable management of the basin across sectors including water resources, environment, fisheries, navigation, trade, tourism, and disaster risk management. Under its provisions, the EAC Treaty remains the supreme legal authority, ensuring that the management of the lake basin aligns with the broader goals of East African integration.

Building on the above foundation, the Lake Victoria Basin Commission Act, 2022 confers full legal autonomy on the LVBC, transforming it from an institution administratively dependent on the EAC Secretariat into a self-standing body corporate with the capacity to manage its affairs independently. By granting corporate personality, financial and administrative autonomy, and authority to directly engage partners, mobilize resources, and harmonize basin-related policies and laws, the Act operationalizes the Protocol's objectives and provides the legal empowerment required for effective implementation of the Commission's transboundary mandate.

Supporting the above legal framework are regional strategies and action plans including the Lake Victoria Basin Strategic Action Programme, the Regional Transboundary Diagnostic Analysis, and

sectoral strategies for water quality management, fisheries, and biodiversity conservation. The LVBC has also developed harmonized regional water quality standards and environmental monitoring protocols. The key regional legal instruments are summarized in Table 8-1 below.

Table 8-1. Status of Key Regional Legal and Policy Instruments for LVB Water Governance

Instrument	Year	Key Provisions for Water Quality Management	Status	Ratification / Adoption
Treaty for the Establishment of the EAC	1999	Mandates cooperation on transboundary pollution control and harmonisation of standards; provides for creation of LVBC.	Binding	Ratified by all Partner States
Protocol for Sustainable Development of the LVB	2003	Establishes LVBC; enshrines equitable use, no-harm, precautionary and polluter-pays principles; requires EIAs and transboundary notification.	Binding	Ratified by Kenya, Rwanda, Tanzania, Uganda; acceded to by Burundi
Lake Victoria Basin Commission Act	2022	Confers legal personality and autonomy on the LVBC; empowers coordination and harmonisation of basin-wide policies, laws, and standards; enables direct resource mobilisation and implementation of regional water quality, environmental protection, and monitoring initiatives.	Binding	Assented to by EAC Heads of State; applicable across EAC Partner States in the Lake Victoria Basin
Protocol on Environment and Natural Resources Management	2006	Comprehensive framework for WQM, pollution control, EIAs, and standards harmonisation.	Not in Force	Ratified by Kenya and Uganda; not ratified by Tanzania
Draft EAC Water Policy	2022	Promotes IWRM; sets provisions for water quality standards, pollution control, and ESIAs.	Draft (non-binding)	Adopted by Sectoral Council; final approval pending
LVB Integrated Water Resources Management Strategy	2023	Strategic actions for watershed management, pollution control, data sharing, and policy harmonisation (2023–2050).	Non-binding	Adopted as a guiding strategy
EAC Industrial & Municipal Effluents Standards	2016	Sets maximum permissible limits for pollutants in wastewater discharges.	Binding	Adopted regionally; implementation varies by Partner State
EAC Potable Water Specification	2017	Establishes minimum requirements for drinking water quality.	Binding	Domesticated by Kenya, Rwanda, Tanzania, Uganda
EAC Water Quality Management Policy Guidelines and Strategic Action Plan	2025	Provides a regional advisory framework for water quality management, covering pollution control, monitoring and data sharing, standards harmonisation, institutional coordination, and capacity development.	Non-binding (Policy Guideline)	Adopted by the EAC Council of Ministers (2025); voluntary implementation by Partner States

Source: *Synthesized from preceding chapters*

8.2.5 The Nile River Basin Cooperative Framework Agreement

The Nile River Basin Cooperative Framework Agreement (CFA) represents a watershed moment in Nile Basin governance. Negotiations for the CFA began in 1999 under the auspices of the Nile Basin Initiative, seeking to establish a permanent legal and institutional framework to replace the colonial-era agreements. The CFA was signed in 2010 by upstream states, with Egypt and Sudan withholding signature due to disagreements over water security provisions.

On October 13, 2024, the CFA entered into force after receiving the required sixth ratification from South Sudan. The ratifying states are Ethiopia, Rwanda, Uganda, Tanzania, Burundi, and South Sudan. The agreement establishes the Nile River Basin Commission (NRBC) as a permanent intergovernmental organization to replace the transitional NBI.

Principles and Provisions

The CFA is built on key principles including equitable and reasonable utilization, the obligation not to cause significant harm, cooperation and information exchange, peaceful settlement of disputes, and prior notification of planned measures. It establishes a framework for benefit sharing rather than water sharing, recognizing that cooperation can create value beyond zero-sum allocation contests.

Implications for the Lake Victoria Basin

- The establishment of the NRBC creates a complex "institutional duality" in the Lake Victoria region. A permanent NRBC with a strong sub-basin arm could potentially duplicate the permanent mandate of the Lake Victoria Basin Commission (LVBC). To avoid institutional conflict, several scenarios for their future relationship are emerging:
- **Designation as Subsidiary Institution**: It is highly probable that the NRBC will designate the LVBC as the "subsidiary institution" responsible for the Lake Victoria sub-basin, leveraging the principle of subsidiarity explicitly incorporated in Article 3 of the CFA (Tekuya, 2024).
- **Functional Division of Labor**: A clear division is required where the NRBC focuses on mainstem Nile issues, basin-wide modeling, and flow regulation, while the LVBC retains primacy over integrated lake basin management and development, including local pollution control, maritime transport, and trade within the EAC framework.
- **Sub-Basin Alignment**: Bilateral agreements such as the Mara and SMM MoUs will likely become "subsidiary instruments" to the CFA. For instance, data collected by the Mara Joint Technical Committee will flow up to the LVBC and subsequently to the NRBC's basin-wide database (NELSAP, 2020).
- **Legal Supremacy and Validation of Upstream Development**: The Cooperative Framework Agreement (CFA) legally validates upstream development by replacing colonial "historical rights" and downstream vetoes with the principle of equitable "water security." This shift creates a strong legal foundation for multilateral financing of infrastructure through the NRBC and LVBC by significantly lowering hydro-political investment risk (Salman, 2024; Tekuya, 2024).
- **Geopolitical Realignment**: The entry into force of the CFA consolidates an "Upstream Bloc" within the Nile system, with EAC Partner States emerging as a coordinated negotiating group through the LVBC in the NRBC framework. However, the rejection of the CFA by Egypt and Sudan entrenches a legal and political bifurcation of the basin. As a result, the NRBC may initially function in practice as a Commission of the Upper Nile, complicating basin-wide responses to shared challenges such as climate change adaptation and invasive species management (Salman, 2024).

8.2.6 Sub-Basin and Bilateral Agreements

Beyond the basin-wide frameworks, Partner States have established bilateral and sub-basin agreements for specific transboundary water bodies:

Kagera Basin Organization (KBO)

The Kagera Basin Organisation (KBO), established through an international agreement signed in 1977 by Rwanda, Burundi, and Tanzania (and acceded to by Uganda in 1981), was mandated to manage shared water resources across the Kagera River Basin. The organization collapsed following the 1994 Rwandan genocide, chronic underfunding ($4.22 million in member state arrears by 2001), and the revival of competing regional frameworks like the East African Community (The Monitor, 2001; The New Humanitarian, 2000). KBO was formally dissolved in 2004 without implementing any major projects (Nile Basin Initiative, 2024).

The Nile Equatorial Lakes Subsidiary Action Program Coordination Unit (NELSAP-CU), established in 1999 under the Nile Basin Initiative, assumed KBO's functions and successfully revived its flagship Regional Rusumo Falls Hydropower Project. With $468.6 million in financing from the World Bank and African Development Bank, the 80 MW facility became operational in November 2023, delivering electricity to approximately 62 million people across three countries. KBO's trajectory demonstrates both the fragility of narrow basin-specific institutions and the resilience of sound projects when supported by broader regional frameworks and substantial international financing.

Mara River Basin

Kenya and Tanzania signed a Memorandum of Understanding in 2015 for joint water resources management of the transboundary Mara River Basin. This agreement establishes a Transboundary Mara River Basin Water Resources Users Association, promotes coordinated catchment management, and facilitates joint monitoring and data sharing. The Mara Basin is critical for biodiversity, supporting the Serengeti-Mara ecosystem, and for livelihoods of over 1 million people.

Lake Chala, Lake Jipe, and Umba River

A 2013 MoU between Kenya and Tanzania addresses the joint cooperative framework for transboundary management of these ecosystems located on the Kenya-Tanzania border. The agreement provides for joint conservation, sustainable use, and benefit sharing.

Sio-Malaba-Malakisi (SMM) River Basin

Shared by Kenya and Uganda, this river system drains into Lake Victoria. An investment framework developed by NBI in 2019 guides coordinated development. The basin faces challenges from agricultural pollution, wetland degradation, and climate variability.

The most recent development in the SMM Basin is the 2025 bilateral agreement between Kenya and Uganda for the Angololo water resources development project. This multipurpose project includes water supply, hydropower generation, and irrigation. Supported by the African Development Bank with $140 million in funding, it represents a new generation of bankable transboundary infrastructure backed by clear legal agreements and dispute resolution mechanisms.

8.2.7 The Missing Layer: Global Water Conventions

The Lake Victoria Basin presents a paradox regarding global international law. As of December 2025, none of the five LVB Partner States—Burundi, Kenya, Rwanda, Tanzania, or Uganda—is a Party to either the 1997 Convention on the Law of the Non-Navigational Uses of International Watercourses (UN Watercourses Convention) or the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE Water Convention). This absence

persists despite significant regional momentum and the active promotion of these instruments by the LVBC Secretariat, creating a "multi-speed" approach to international water law across the basin.

The Accession Paradox and "Treaty Congestion"

The primary barrier to accession is not legal incompatibility but rather "treaty congestion" and a perception of redundancy. The foundational regional instruments—the LVB Protocol (2003) and the Nile CFA (2010)—already "domesticate" the core principles of the global conventions, such as "equitable and reasonable utilization" and the "obligation not to cause significant harm". Consequently, policymakers often view the global conventions as adding an additional layer of bureaucratic obligation without offering immediate distinct political wins that are not already covered by regional treaties. Furthermore, the immense diplomatic capital required to finalize the Nile CFA ratification process exhausted significant capacity within the region's ministries.

The Strategic Case for Accession: Finance and Stability

With the Nile CFA now in force, the strategic argument for joining the global conventions has shifted from "legal necessity" to "financial viability."

- **Unlocking Climate Finance:** International financial institutions (IFIs) increasingly view adherence to global water conventions as a proxy for "good governance." Accession signals a robust framework for conflict resolution, thereby "de-risking" transboundary infrastructure projects—such as the Angololo dam—and lowering the cost of capital.
- **Global Solidarity:** Accession by LVB states would align them with a growing bloc of African nations (including Zambia, Namibia, and Ghana) that are championing equitable water use globally, enhancing their diplomatic standing in broader climate negotiations.
- **Dispute Resolution:** While the LVBC provides a dialogue forum, the global conventions offer rigorous, non-political dispute settlement mechanisms (such as fact-finding commissions) that act as an insurance policy against future escalation.

8.2.8 National Legal Frameworks and Harmonization

Each Partner State has established national water legislation that governs resource allocation, quality standards, and environmental protction:

- **Kenya**: Water Act 2016 - Establishes the Water Resources Authority (WRA) and provides for IWRM, catchment-based management, and water user associations.
- **Uganda**: The Water Act 1997 (Cap. 152) - Creates a permit system for water use, establishes water quality standards, and provides for catchment management.
- **Tanzania**: Water Resources Management Act 2009 (No. 11) - Institutes basin water boards, water user associations, and integrated water resources management.
- **Rwanda**: Law No. 49/2018 determining the use and management of water resources - Establishes Rwanda Water Resources Board and catchment-based management.
- **Burundi**: Loi N°1/02 du 26 mars 2012 portant Code de l'Eau - Provides framework for water resources management and protection.

While these national frameworks share common principles rooted in IWRM, implementation remains uneven. Challenges include limited enforcement capacity, inadequate resources for monitoring and compliance, weak coordination between national and regional levels, and insufficient harmonization of standards and procedures across borders.

8.3 Institutional Architecture Within the Lake Victoria Basin

8.3.1 Regional Institutions

The Lake Victoria Basin Commission (LVBC)

The Lake Victoria Basin Commission (LVBC) was established under the 2003 Protocol for Sustainable Development of Lake Victoria Basin and became operational in 2004. Headquartered in Kisumu, Kenya, the LVBC is a specialized apex institution of the EAC with international legal personality. Unlike the transitional Nile Basin Initiative, the LVBC is a permanent treaty-based body mandated to coordinate the sustainable development of the Lake Victoria basin.

The LVBC's mandate extends beyond water resources to include: coordinating all interventions on the lake and its basin; promoting socio-economic development; conserving the environment and natural resources; coordinating stakeholders; managing shared fisheries; ensuring navigational safety; promoting cooperation in research and information exchange; harmonizing national policies and laws; and mobilizing resources for sustainable development.

The LVBC operates under a three-tiered governance structure:

- **Sectoral Council** on Lake Victoria Basin Development: The apex policy organ composed of ministers from Partner States, meeting twice yearly to provide strategic direction
- **Policy Steering Committee**: Comprising Permanent Secretaries, meets quarterly to oversee implementation and coordinate with national governments
- **LVBC Secretariat**: Led by an Executive Secretary, provides technical and administrative support, coordinates programs, and facilitates stakeholder engagement.

Lake Victoria Fisheries Organization (LVFO) and Sectoral Specialisation

The Lake Victoria Fisheries Organization (LVFO) was established in 1994 as a specialized agency under the EAC Treaty to promote sustainable utilization of fisheries. The LVFO coordinates research, harmonizes policies, and facilitates joint management of the shared fishery resource. Since 2003, the LVFO has been integrated into the LVBC framework, with both institutions working collaboratively while maintaining distinct operational mandates.

Institutional Complementarity between the Lake Victoria Basin and the Nile Basin Framework

The governance of the Lake Victoria Basin (LVB) is shaped by a distinctive institutional configuration that links regional integration under the East African Community with basin-wide cooperation across the Nile system. This arrangement brings together the Lake Victoria Basin Commission (LVBC), operating under the East African Community, and the Nile Basin Initiative (NBI), the cooperative framework for all Nile riparian states. While this duality inherently creates areas of overlap, it has progressively evolved into a structured system of coordination and functional complementarity.

- **Institutional Mandates and Areas of Overlap:** Established in 1999 and headquartered in Entebbe, Uganda, the NBI was conceived as a transitional mechanism to promote cooperative development, equitable utilization, and shared benefits across the Nile Basin. Within the equatorial region, its investment and project-preparation functions are implemented through the Nile Equatorial Lakes Subsidiary Action Program (NELSAP). Because the Lake Victoria Basin is hydrologically a sub-basin of the Nile,

LVBC's geographic mandate falls entirely within NELSAP's operational area. Functional reviews indicate that a significant proportion of statutory responsibilities—estimated at roughly three-quarters—are potentially overlapping, particularly in planning, environmental management, and water resources development.

- **Hydrological and Geopolitical Linkages:** Beyond institutional considerations, the Lake Victoria Basin occupies a pivotal position within the wider Nile system. As the headwaters of the White Nile, with outflow at Jinja, the basin functions as a regional "water tower" whose hydrological conditions influence downstream states as far as Sudan and Egypt. Land-use change, water abstractions, pollution loads, and hydraulic infrastructure within the LVB therefore have consequences well beyond its immediate riparian countries. This upstream–downstream interdependence has historically generated geopolitical sensitivities, underscoring the strategic importance of the LVBC–NBI partnership as a stabilizing mechanism that aligns sub-basin management with basin-wide cooperation.
- **Managing Dualism: The 2006 EAC–NBI Memorandum of Understanding:** To address the risks of duplication and institutional competition, the EAC and NBI signed a Memorandum of Understanding on 12 July 2006. This agreement formalized a principle of "cooperative distinctiveness," clearly articulating a division of labor between the two institutions. Under this framework, NELSAP concentrates on investment preparation and implementation of regional infrastructure (the "hardware"), while LVBC leads on policy coordination, environmental stewardship, and regional integration processes (the "software"). Over time, this delineation has shifted the relationship from one of conflict avoidance to one of deliberate and mutually reinforcing collaboration.
- **Operational Synergies and Joint Delivery:** Institutional complementarity has translated into tangible operational synergies, particularly since the adoption of a joint Strategic Action Plan in 2017. Three areas are especially illustrative.
    - **First**, the Nile Basin Regional Hydro-Meteorological Monitoring System integrates data from more than 60 stations, with real-time transmission to both NBI in Entebbe and LVBC in Kisumu. This shared architecture eliminates information silos, simultaneously supporting basin-wide flow modeling and lake-level safety monitoring.
    - **Second**, the Nile Cooperation for Climate Resilience (NCCR) programme—a USD 140 million initiative financed by the World Bank and implemented from 2020 to 2028—demonstrates effective joint technical delivery in climate forecasting, early-warning systems, and knowledge platforms.
    - **Third**, collaboration extends to large-scale transboundary infrastructure, including regional power interconnections, navigation improvements, and multipurpose water resources developments such as the Angololo project between Kenya and Uganda.

8.3.2 National Institutions

The key national institutions are the following:

- **Uganda** – The **National Environment Management Authority (NEMA)** leads environmental regulation, environmental impact assessment, compliance monitoring, and reporting, supported by sector agencies for water, wetlands, and fisheries. Integrated water resources management is led by the Directorate of Water Resources Management (DWRM) under the Ministry of Water and Environment, with catchment-level implementation through four Water Management Zones. The DWRM also coordinates transboundary water resources cooperation activities.
- **Kenya** – The **Water Resources Authority (WRA)** coordinates water resources management,

water quality monitoring, and pollution control in the two LVB catchments (Lake Victoria North and Lake Victoria South), working alongside environmental and fisheries agencies. Transboundary water cooperation and engagement with LVBC are overseen by the Transboundary Waters Department within the Ministry of Water, Sanitation and Irrigation.

- **Tanzania** – The **National Environmental Management Council (NEMC)** serves as the primary regulatory authority for environmental compliance and pollution control, complemented by the Department of Water Resources Management under the Ministry of Water, the Lake Victoria Basin Water Board, and national-level fisheries, livestock, irrigation, forestry and energy institutions responsible for sectoral implementation.
- **Rwanda** – Environmental regulation and ecosystem restoration are led by the **Rwanda Environment Management Authority (REMA)**, with strong linkages to land-use planning and climate policy. Water resources management is the responsibility of the Rwanda Water Resources Board (RWB), an autonomous public body under the Ministry of Environment, particularly active in the Kagera sub-basin.
- **Burundi** – As an upstream contributor to the basin, institutional responsibility is shared among sector ministries and agencies, including the Ministry of Environment, Agriculture and Livestock (MINEAGRIE) for policy and land-use regulation; the Office Burundais pour la Protection de l'Environnement (OBPE) for environmental enforcement and monitoring; the Geographic Institute of Burundi (IGEBU) for hydrological and meteorological data collection; and the Ministry of Hydraulics, Energy and Mines for water supply and sanitation services.

8.4 Key Programmes and Development Results

8.4.1 Flagship Environmental and IWRM Programmes

Lake Victoria Environmental Management Projects

The Lake Victoria Environmental Management Project series represents the largest and most sustained intervention in basin governance:

- **LVEMP I (1997-2005)**: The first phase achieved remarkable success in controlling water hyacinth through biological control methods, reducing infestation by over 95%. It also established regional institutions (LVBC, LVFO), created water quality monitoring networks, and built capacity for collaborative research. However, sustainability proved challenging as water hyacinth rebounded periodically when maintenance of biological control weakened.
- **LVEMP II (2009-2018)**: The second phase emphasized scaling up successful approaches and strengthening institutional capacity. Key achievements included expanding the water quality monitoring network, supporting catchment-based management through Water Resource User Associations, upgrading wastewater treatment facilities, and promoting community-based natural resource management. The World Bank's 2018 completion report noted mixed results: strong progress on institutional development but limited impact on overall basin environmental quality due to insufficient coverage and maintenance challenges.
- **LVEMP III (2019-2025)**: The current phase focuses on strengthening transboundary cooperation, enhancing resilience to climate change, and promoting sustainable livelihoods. It emphasizes nature-based solutions, payment for ecosystem services, and climate-smart agriculture. Results to date show promise but implementation has been affected by COVID-19 disruptions and continued resource constraints.

LVB Integrated Water Resources Management Programme (LVB IWRMP)

This LVBC-led program promotes integrated approaches to water resources management, emphasizing catchment-based planning, stakeholder participation, and ecosystem-based management. Pilot catchments have demonstrated improved coordination and stakeholder engagement, though scaling remains constrained by financing.

8.4.2 Water Supply and Sanitation Initiatives

The Lake Victoria Water and Sanitation Initiative (LVWATSAN) aimed to improve access to safe water and adequate sanitation in 15 towns across all five Partner States. Supported by the African Development Bank and African Water Facility, the program invested in treatment plants, distribution networks, and institutional capacity building. While infrastructure was successfully constructed, sustainability challenges emerged around operation and maintenance, cost recovery, and institutional management.

Access to improved water sources in basin towns increased from approximately 55% to 68% between 2010 and 2020, while access to improved sanitation rose from 40% to 52%. However, wastewater treatment coverage remains critically low, with most urban wastewater entering the lake untreated.

8.4.3 Navigation and Regional Infrastructure Initiatives

The Lake Victoria Basin Commission (LVBC) is implementing navigation improvement projects valued at approximately USD 25 million to modernize and secure lake transport across Lake Victoria. The investments focus on upgrading key port and landing facilities, dredging critical navigation channels, and installing essential safety and navigation infrastructure. Port upgrades include improvements to berths, jetties, cargo and passenger handling areas, and intermodal connections to road and rail networks to reduce congestion and improve efficiency.

8.4.4 Complementary Regional Programmes

Beyond LVBC-led initiatives, several high-impact regional programs implemented by partner organizations play a complementary role in advancing sustainable development, climate resilience, and economic integration across the Lake Victoria Basin.

- **Kagera Transboundary Agro-ecosystem Management Programme (Kagera TAMP):** Supported by FAO and the Global Environment Facility, Kagera TAMP addresses land degradation, agricultural intensification, and ecosystem restoration in the Kagera basin. The program has successfully demonstrated sustainable land management practices, improved crop yields, and enhanced community-based natural resource management across 13 pilot sites in Burundi, Rwanda, and Tanzania.
- **Nile Cooperation for Climate Resilience (NCCR):** This joint NBI-LVBC program strengthens climate resilience through improved forecasting, early warning systems, and adaptive management. Key achievements include establishment of the regional hydromet monitoring system, development of climate information services, and capacity building for climate risk assessment.
- **Nile Equatorial Lakes Regional Power Interconnection**: A $257 million project linking power grids of Uganda, Kenya, Rwanda, Burundi, and Tanzania, enabling electricity trade and improving energy security.
- **Angololo Multipurpose Project**: The recent Kenya-Uganda agreement for a $140 million project providing water supply, hydropower (45 MW), and irrigation, demonstrating new generation of bankable transboundary infrastructure backed by robust legal frameworks.

8.5 Dividends of Cooperation

8.5.1 Peace and Stability Dividend

Transboundary cooperation in the Lake Victoria Basin has contributed significantly to regional peace and stability. The cooperative frameworks have provided mechanisms for managing potential conflicts over shared resources, building trust through joint technical initiatives, and creating economic interdependencies that raise the costs of conflict. Over two decades of cooperation, there have been no major water-related conflicts among Partner States, contrasting sharply with water conflicts observed in other African transboundary basins.

The institutionalization of dialogue through the LVBC and related platforms has created regular channels for communication, dispute resolution, and collaborative problem-solving. This has contributed to broader EAC regional integration objectives, supporting political stability and economic development.

8.5.2 Economic Integration Benefits

Cooperation has facilitated economic integration through enhanced trade, regional value chains, and tourism development. The navigation improvement projects have reduced transport costs and improved market access for fishing communities. The power interconnection enables electricity trade, improving energy security and potentially reducing costs. Joint management of fisheries has supported sustainable exploitation of a resource worth over US$1.12 billion annually, directly supporting livelihoods of over 200,000 fishers and millions more in processing and trade.

The designation of the basin as a Regional Economic Growth Zone has attracted investment in infrastructure, agribusiness, and tourism. Lake Victoria's tourism potential—including sport fishing, beach resorts, and wildlife tourism—has been enhanced through coordinated marketing and improved environmental quality in some areas.

8.5.3 Environmental and Social Co-Benefits

Cooperation has generated environmental and social co-benefits including:

- **Shared Environmental Monitoring**: Regional water quality monitoring networks provide data for evidence-based decision-making and early warning of environmental threats.
- **Biodiversity Conservation**: Collaborative approaches to managing shared ecosystems have supported conservation of migratory species, wetlands, and critical habitats that transcend national boundaries.
- **Climate Resilience Building**: Joint climate information services and early warning systems enhance adaptive capacity across all Partner States.
- **Public Health Improvements**: The Population-Health-Environment (PHE) approach piloted in lakeside communities has demonstrated integrated benefits, improving health outcomes while strengthening environmental stewardship.
- **Gender Mainstreaming**: Regional programs have increasingly integrated gender considerations, supporting women's participation in resource management and recognizing their critical roles in water management, fisheries, and agriculture.

8.6 Stakeholder Participation and Civil Society Engagement

8.6.1 Multi-stakeholder Platforms

Effective transboundary governance requires meaningful participation of diverse stakeholders beyond governments. The LVBC has established several platforms for stakeholder engagement:

- **Lake Victoria Basin Civil Society Forum**: Brings together NGOs, CBOs, and civil society organizations to provide input on regional policies and programs
- **Sectoral Technical Committees**: Expert groups covering water resources, fisheries, environment, transport, and other sectors provide technical advice and review policies
- **Academic and Research Networks**: Universities and research institutions collaborate on basin-wide studies, monitoring, and knowledge generation
- **Private Sector Engagement**: Through platforms like the East African Business Council, private sector actors contribute to investment planning and economic development strategies

While these platforms exist formally, participation remains uneven. Civil society representatives often lack resources to attend regional meetings, and their inputs do not always translate into policy changes. Strengthening these platforms requires dedicated funding, clearer mechanisms for incorporating stakeholder input, and transparency in decision-making.

8.6.2 Local Government Engagement

Across the East African Community (EAC), local governments play a frontline role in natural resources management, particularly in areas such as environmental protection, land-use control, solid waste management, sanitation, and the regulation of shoreline and wetland activities. As the tier of government closest to communities, they are often the first responders to environmental degradation and the primary interface for citizen engagement in resource stewardship.

Within the Lake Victoria Basin, this role is supported by a unique regional mechanism for structured local government cooperation—the Lake Victoria Region Local Authorities Cooperation (LVRLAC). Established in 1997, LVRLAC brings together over 130 local authorities (counties, districts, and municipalities) from Kenya, Tanzania, and Uganda to address shared urban and environmental challenges.

Strategic Function: LVRLAC operates as a horizontal peer-learning and advocacy platform, enabling mayors and technical officers to exchange practical solutions on waste management, sanitation, market hygiene, and urban planning without waiting for national-level directives. It also serves as a collective voice for local governments in regional policy spaces (Global Social Economy Forum, 2020).

Successes: The network has supported the harmonization of hygiene standards in landing sites and markets and promotes structured peer learning, allowing cities to replicate proven waste and sanitation practices across national boundaries.

Challenges: LVRLAC's effectiveness remains constrained by financial fragility. Heavy reliance on membership fees and donor funding limits sustained participation by smaller and less-resourced authorities, with agenda-setting often dominated by larger urban centers such as Kisumu and Entebbe.



Figure 8-2. *Members of the General Assembly of LVRLAC 2024 make a visit Luchelele Fish Cages, Mwanza, Tanzania.*

8.6.3 Catchment Committees and Community-Based Organizations

From Policy to Practice: Community-Led Catchment Governance

Across the Lake Victoria Basin and the wider EAC region, Catchment Committees and Water Resource Users Associations (WRUAs)/Water Users Associations (WUAs) form the backbone of community participation in watershed governance. Established under national water laws and basin frameworks, they operationalize Integrated Water Resources Management (IWRM) at the catchment level by linking state regulation with local resource use.

Catchment Committees are statutory sub-basin organs of national water authorities. They coordinate water allocation across multiple WRUAs/WUAs, advise regulators on permitting and compliance, oversee catchment management and drought-response measures, resolve inter-sectoral disputes, and translate national water policy into local administrative action.

WRUAs/WUAs, by contrast, are legally recognized but non-governmental, community-based organizations representing farmers, industries, pastoralists, and domestic users at the micro-catchment scale. Their authority derives from social legitimacy and collective action rather than statutory enforcement. Their core roles include negotiating local water-sharing arrangements, preventing and resolving day-to-day water-use conflicts, protecting riparian zones and wetlands, mobilizing communities for pollution control and source protection, and representing local users in engagements with basin authorities. **Figure 8-3** shows a local farmer and member of a Water User Association integrating watershed management measures on her farm.

Beach Management Units (BMUs) are co-management institutions bringing together fishers, local authorities, and fisheries officials to manage fishing activities at landing sites. They enforce fishing regulations, collect data, resolve conflicts, and promote sustainable practices.

Together, these institutions provide a multi-tiered

governance bridge that embeds national water regulation within locally grounded management systems.

Demonstrated Successes

Where the statutory authority of Catchment Committees aligns with the social legitimacy of WRUAs/WUAs, the dual governance system has delivered measurable gains in water security, conflict reduction, and source protection.

At community level, WRUAs/WUAs have proven effective in stabilizing water-sharing during scarcity. In the Pangani Basin, negotiated dry-season rationing reduced recurrent upstream–downstream conflicts and improved predictability for irrigators, hydropower operators, and environmental flows (Lalika et al., 2015). In the Mara Basin, the Mara River WRUA mobilized large-scale compliance with riverbank protection and helped sustain momentum for Mau Forest rehabilitation, with clear downstream dry-season flow benefits.

At sub-basin scale, Catchment Committees add value through coordination and escalation, particularly during droughts when fragmented local negotiations are insufficient. In better-functioning systems, they have enabled cross-sector alignment of abstraction controls, faster dispute resolution, and consistent enforcement of catchment rules across administrative boundaries.

Illustrative cases of how stakeholder engagement operates in practice—across diplomacy, rights-based advocacy, benefit-sharing, and eco-enterprise—are presented in **Textbox 8-1**.



Figure 8-3. *A farmer in Uganda has integrated trees on her farm. Individuals and associations of water users complement the conservation efforts of public authorities. (Source: Trees for the Future).*

Textbox 8-1: Illustrative Cases of Stakeholder Engagement and Public Participation in the Lake Victoria Basin

Mara River Basin (Kenya–Tanzania): From Conflict to Cooperation

The Mara River supports the globally significant Serengeti–Mara ecosystem but faced severe degradation and cross-border tensions from deforestation in the Mau Escarpment, unregulated irrigation expansion, and mining activities in Tanzania. Rising dry-season water stress triggered tensions between upstream Kenyan users and downstream Tanzanian conservation and tourism stakeholders. A Transboundary Water Users Forum enabled structured dialogue among users, regulators, and conservation actors, contributing to a bilateral MoU on joint basin management. The Mara River WRUA mobilized farmers to terrace 995 ha, reducing sediment loads and improving downstream water quality—demonstrating effective bottom-up hydro-diplomacy.

Yala Swamp (Kenya): Community Rights and Participatory Land-Use Planning

Allocation of large tracts of Yala Swamp to Dominion Farms for commercial rice cultivation displaced fishing and papyrus-harvesting communities, restricted access to ecosystem services, and introduced pesticide risks through aerial spraying. Communities were excluded from the original decision-making process, leading to protests, sabotage, and litigation threats. Civil society organizations, led by Nature Kenya and the Yala Ecosystem Site Support Group, supported a Participatory Ecosystem Services Assessment that quantified the wetland's livelihood value. Community petitions to the National Land Commission halted further allocations and compelled the county government to prepare a participatory Land Use Plan (LUP) and Strategic Environmental Assessment (SEA). The resulting zoning framework formally balanced conservation, community use, and commercial investment, demonstrating how CSO-facilitated participation can correct power asymmetries between investors, governments, and local communities (BirdLife International, 2025).

Sio–Malaba–Malakisi Basin (Kenya–Uganda): Benefit-Sharing as a Cooperation Strategy

The SMM basin faces chronic pollution, sedimentation, and flood risk, compounded by weak cross-border coordination. Rather than going for contested allocation negotiations, stakeholders adopted a Benefit Opportunities Assessment Dialogue approach, reframing cooperation around shared economic and environmental gains. This enabled joint investment priorities in pollution control, flood mitigation, and cross-border trade, building trust through early-win interventions. The case demonstrates how benefit-sharing can de-risk transboundary cooperation where zero-sum allocation politics would otherwise stall progress (Nile Basin Initiative, 2019).

Operational Weaknesses

Despite these strengths, the Catchment Committee–WRUA/WUA system faces persistent operational constraints. **Catchment Committees** are weakened by chronic under-resourcing of basin authorities—limited budgets, transport, and staffing reduce field supervision and undermine effective permit enforcement, enabling inequitable abstraction and elite capture by powerful upstream users (Amankwaa et al., 2024).

WRUAs/WUAs face sustainability and capacity challenges. Many remain heavily donor-dependent, with participation and operations declining sharply after project closure. In the Mara Basin, post-project stagnation required the introduction of income-generating activities to stabilize financing. Technical capacity gaps further weaken performance; in Burundi, inadequate training, spare-parts supply chains, and high volunteer turnover have led to frequent water-point failures and loss of institutional memory (ALNAP, 2001).

BMUs, while having strengthened community involvement in fisheries management, face multiple challenges including elite capture, gender inequality, and limited enforcement authority.

Civil Society Organisations

Civil society organizations play a vital role in giving communities a voice. They support public awareness, help communities engage with decision-makers, mediate conflicts, and promote accountability. Women, youth, and traditional leaders are increasingly involved through these platforms, ensuring that decisions reflect diverse perspectives and local knowledge. However, participation is still uneven and often depends on short-term project funding, which can limit continuity and long-term impact.

Textbox 8-2: Osienala – Using Radio to Give Communities a Voice



Osienala, which means "friends of the lake" in Luo, is a civil society organization based in Kisumu, Kenya, that has been working with Lake Victoria communities since 1992. The organization uses a distinctive approach to environmental awareness and community empowerment: Radio Lake Victoria (RLV), a community radio station that brings Lake Victoria issues directly into people's homes, boats, and workplaces.

Through RLV, Osienala raises awareness about water quality, sustainable fishing practices, wetland protection, and climate change impacts on the lake. The radio programs feature local voices—fishers, farmers, women's groups, and youth—who share their experiences and knowledge. Listeners learn practical solutions, hear about government policies affecting them, and participate in discussions through phone-ins and community forums.

This radio-based approach helps reach fishing communities on distant islands, farmers in remote catchments, and urban residents alike—many of whom might otherwise not engage with environmental programs.

By giving communities a platform to speak, question, and learn, Osienala exemplifies how civil society can bridge the gap between technical experts, government authorities, and the people whose daily lives depend on the lake's health.

8.6.4 Private Sector Engagement

The role of the private sector in the Lake Victoria Basin is evolving from that of a primary polluter to an emerging partner in green growth, reflecting growing recognition that environmental sustainability and long-term business viability are mutually reinforcing.

Through the LVBC's ***Engaging Private Sector for Green Growth (EPSGG)*** project, industries are being incentivized to adopt Resource Efficient and Cleaner Production (RECP) practices that reduce water use, recover waste, and improve energy efficiency while delivering direct cost savings. The initiative targets both SMEs and large firms and strengthens National Cleaner Production Centres to support sustained industrial transformation .

The East African Business Council (EABC) plays a central role in integrating sustainability into regional private-sector policy dialogue, linking trade facilitation and standards harmonization with environmental performance, and promoting investment in green technologies (East African Business Council, 2025).

In urban sanitation, where public finance is insufficient, private capital is increasingly being mobilized through public–private partnerships. Under the Lakewide Inclusive Sanitation strategy—estimated at USD 1.9 billion—investment in fecal sludge management and waste-to-energy systems is positioning sanitation as a viable green business opportunity (World Bank, 2025).

8.7 Knowledge Management and Data Systems

8.7.1 Regional Hydro-Meteorological Monitoring

The Nile Basin Regional Hydro-Meteorological Monitoring System represents a flagship achievement in joint technical cooperation. With over 60 stations across the basin transmitting data in real-time to both NBI and LVBC, the system provides critical information for water resources planning, flood forecasting, and drought monitoring.

However, gaps and challenges persist: uneven station density leaving some sub-basins under-monitored; equipment maintenance issues causing data gaps; limited capacity for data analysis and interpretation; and insufficient integration with national decision-making systems. Strengthening the system requires sustained investment in equipment maintenance, technical capacity, and data management platforms.

8.7.2 Environmental Monitoring and Knowledge Gaps

Regional water-quality monitoring networks track key parameters across Lake Victoria and its major tributaries, but coverage remains inadequate relative to the basin's scale and ecological complexity. Persistent knowledge gaps include limited understanding of pollutant sources and transport pathways, insufficient characterization of groundwater resources, weak biodiversity and ecosystem-health baselines, and limited capacity for integrated modelling that links land use, water quality, and ecosystem response.

Although long-term datasets exist for selected parameters and stations, inconsistencies in spatial coverage, sampling frequency, and data integration constrain basin-wide diagnostics and forecasting. Strengthening harmonised monitoring protocols, expanding station density, and sustaining long-term observation programmes are therefore critical priorities for evidence-based management.

8.7.3 Research, Innovation, and Public Awareness

Knowledge generation, innovation, and public engagement form the intellectual and social foundations of adaptive transboundary water governance. While regional research collaboration has advanced through platforms such as the Lake Victoria Research Initiative, the translation of research outputs into policy and operational decision-making remains uneven, underscoring the need for a stronger science–policy interface.

- **Bridging Science and Policy:** The proposed LVBC Centre of Excellence could serve as a regional hub for data synthesis, innovation, and policy support. Enhanced partnerships with universities and research institutes across Partner States would strengthen collaborative research on climate resilience, pollution control, and **ecosystem** restoration, ensuring that management decisions are grounded in credible and current evidence.
- **Public Awareness and Education:** Sustained environmental improvement depends on informed and engaged citizens. Initiatives such as ***The Flipflopi Project***, which mobilised communities against plastic pollution, demonstrate the power of civic action in driving behavioural change and policy reform. Expanding environmental education through schools, media, and community networks can strengthen ecological literacy, foster stewardship, and build broad-based support for accountability and long-term protection of the Basin's ecosystems.

8.8 Performance of Basin Management Institutions

The Lake Victoria Basin (LVB), which has been designated as an area of common economic interest, is supported by a multi-layered institutional architecture spanning regional coordination bodies and national implementing agencies. Below is brief synopsis on the performance of the institutional framework in the basin.

8.8.1 Regional Institutions

Lake Victoria Basin Commission (LVBC)

The LVBC is the principal regional body mandated to coordinate sustainable development in the basin. Its performance reflects **high strategic and technical competence,** but **limited operational depth.**

Key strengths include:

- Development of robust regional planning instruments, including strategic plans aligned to results-based management.
- Establishment of basin-wide information and monitoring platforms that support evidence-based planning.
- Strong capacity to mobilise external financing and coordinate large, multi-country investment programmes.
- Leadership in cross-sectoral initiatives such as sanitation, navigation safety, and environmental contingency planning.

Key weaknesses persist:

- Chronic understaffing relative to mandate, with long-standing vacancies in senior and technical positions.
- Heavy dependence on donor financing, compounded by irregular Partner State contributions, which undermines financial predictability.
- Limited physical infrastructure and equipment for monitoring and field operations.
- Weak translation of regional policies into national action, reflecting insufficient authority and resourcing of national focal points.

Overall, LVBC performs well as a strategic and coordinating institution, but remains constrained as an operational driver of change.

Lake Victoria Fisheries Organization (LVFO)

LVFO manages one of the world's largest freshwater fisheries and exhibits **strong scientific and technical capacity**, particularly in stock assessment and regional harmonisation.

Notable achievements include:

- Long-term hydro-acoustic surveys and improved fisheries data systems.
- Harmonised regional standards for licensing, cage aquaculture, and fisheries management.
- Development of regional plans to address fishing capacity and sustainability.

However, **implementation effectiveness is weak**:

- Illegal, unreported, and unregulated (IUU) fishing remains widespread.
- Fish stocks, particularly Nile perch, have declined sharply despite available scientific evidence.
- Co-management systems, notably Beach Management Units, suffer from weak governance, under-resourcing, and declining legitimacy.

LVFO's experience highlights a recurring basin-wide pattern: sound science without commensurate enforcement capacity.

8.8.2 National Institutions

At national level, environmental and water management institutions show high variability in capacity and effectiveness, shaped by economic conditions, institutional maturity, and political prioritisation.

Across all Partner States, the institutional landscape is characterised by broadly adequate legal and policy frameworks that are generally aligned with regional commitments and agreed basin-wide objectives. Most countries have established the necessary laws, regulations, and strategies to support sustainable management of water resources, ecosystems, and related sectors. However, the capacity to translate these frameworks into effective action on the ground remains uneven. Implementation is particularly weak at catchment and local levels, where responsibilities are extensive but technical expertise, staffing, and financial resources are often limited. As a result, monitoring systems, regulatory enforcement, and coordination across sectors such as water, environment, agriculture, and urban development remain under-resourced, constraining the effectiveness of national institutions and contributing to persistent gaps between policy intent and observed outcomes in the Lake Victoria Basin.

Selected national performance trends:

- **Rwanda** demonstrates strong political commitment to watershed restoration, with measurable success in soil erosion control and wetland rehabilitation, though technical capacity and transboundary coordination gaps persist.
- **Uganda** has improved administrative efficiency and reporting systems, but enforcement challenges remain, particularly for wetlands and industrial pollution.
- **Kenya** possesses relatively mature water institutions and planning frameworks, yet faces severe sedimentation and riparian encroachment driven by high population pressure and land-use change.
- **Tanzania** has established regulatory systems, but struggles with industrial compliance and municipal wastewater management, especially in urban lakefront areas.
- **Burundi**, as an upstream contributor, has made progress in policy alignment and catchment interventions but remains severely constrained by limited resources, infrastructure deficits, and post-conflict institutional fragility.

These asymmetries complicate basin-wide outcomes, as environmental pressures generated in one part of the basin propagate across borders.

8.8.3 Synthesis and Outlook: The Framework–Function Gap in Practice

Institutional performance in the Lake Victoria Basin is marked by a persistent gap between well-developed governance frameworks and their practical execution. At the regional level, sophisticated policies, strategies, and technical tools have been established, particularly in water quality management, fisheries regulation, and basin planning. However, these frameworks are often not matched by clear implementation pathways, adequate resourcing, or enforceable accountability mechanisms. As a result, regional standards exist largely on paper, while monitoring, compliance, and enforcement on the ground remain inconsistent and fragmented.

This framework–function gap is reinforced by weak coordination across governance levels. Although formal mechanisms for collaboration between regional bodies and national institutions are in place, operational coordination remains limited. Information flows are uneven, joint planning is sporadic, and decision-making authority is frequently misaligned with responsibility. National and local institutions—tasked with enforcement and service delivery—often lack the financial, technical, and human resources required to implement regional commitments effectively. This imbalance is particularly evident in upstream catchments, where limited capacity has basin-wide consequences.

Resource mismatches further constrain performance. Regional institutions such as the LVBC carry expansive mandates across multiple sectors, yet operate with staffing levels and budgets that are insufficient for sustained implementation. At the same time, weak accountability mechanisms allow commitments to be made at regional level without assurance of follow-through at national level, with few consequences for delayed action or non-compliance.

Looking ahead, improving institutional effectiveness in the basin will depend less on the development of new policies and more on consolidating and strengthening existing arrangements. Priority actions include reinforcing the staffing, financing, and operational autonomy of regional institutions; improving the predictability of Partner State contributions to reduce dependence on external funding; and providing targeted capacity support to weaker national systems. Equally critical is the establishment of stronger accountability mechanisms that link regional agreements to national implementation, alongside a decisive shift toward enforcement and investment in core infrastructure—particularly wastewater treatment, catchment restoration, and fisheries management.

8.8.4 Political Economy of Sovereignty vs Regionalism

The framework-function gap partly reflects inherent tensions between national sovereignty and regional cooperation. Each Partner State faces domestic pressures to prioritize immediate national development needs over longer-term regional environmental sustainability. Political incentives favor visible infrastructure investments over less tangible investments in environmental management or regional coordination.

Water resources management often competes with other priorities in national budgets. Environmental agencies typically lack political clout compared to agriculture, energy, or infrastructure ministries. Regional commitments can be subordinated to domestic political calculations, particularly where regional cooperation imposes costs on specific constituencies.

8.8.5 Vertical and Horizontal Coordination Challenges

Effective basin governance requires coordination across multiple dimensions—vertical (regional-national-local), horizontal (across sectors), and temporal (short-term vs. long-term). Each dimension presents distinct challenges:

- **Vertical Coordination**: Weak linkages between regional policies and national implementation; limited authority of national focal points; insufficient resources at local levels; poor information flow between levels.
- **Sectoral Coordination**: Water management intersects with agriculture, energy, transport, health, and environment, but coordination mechanisms remain weak. Sectoral ministries pursue separate agendas with limited integration.
- **Temporal Mismatches**: Political cycles favor short-term visible results, while environmental management requires long-term sustained effort. Project cycles create gaps in continuity.

8.8.6 Accountability and Enforcement Deficits

Regional governance suffers from weak accountability mechanisms. Partner States can sign agreements and protocols without ensuring implementation, facing few consequences for non-compliance. The LVBC lacks enforcement authority, relying on persuasion and coordination rather than binding compliance mechanisms.

Strengthening accountability requires: clear performance indicators for national commitments; regular reporting and peer review mechanisms; transparency in decision-making and resource allocation; strengthened dispute resolution procedures; and political-level engagement to ensure high-level commitment and follow-through.

8.9 Strengthening Capacity for Effective Governance

Addressing the systemic gaps identified in previous chapters requires a comprehensive strengthening of financial, human, and institutional capacity. The transformation of the Lake Victoria Basin governance system—from a donor-dependent coordination mechanism into a self-sustaining and effective management framework—depends on sustainable financing, skilled personnel, and strong science–policy linkages supported by public awareness.

8.9.1 Financial Sustainability: The Critical Challenge

Sustainable financing is the foundation of effective basin governance. Without predictable and diversified resources, institutions like the LVBC remain constrained by donor cycles that limit long-term planning and operational continuity. Building a resilient financial base therefore requires both reducing dependency and innovating new funding models that can support the Basin's evolving needs.

- **Breaking Donor Dependency**: The basin's governance framework has long relied on external financing from partners such as the World Bank, the European Union, and the Government of Germany. While these resources have enabled transformative programs—including LVEMP, LVWATSAN, and the ongoing IWRM Programme—this dependence on short-term projects has created structural fragility. Once projects end, critical functions such as monitoring, enforcement, and coordination often lapse, eroding institutional memory and capacity. Achieving long-term sustainability demands a gradual shift from reliance on external donors toward stronger domestic financing and predictable Partner State contributions.
- **Innovative Financing Mechanisms**: To secure sustainable and diversified funding, the Basin can draw lessons from other transboundary water organizations (**Table 8-2**). Establishing a Regional Trust Fund with capital endowments would provide stable, interest-generated income to support core functions. Introducing polluter-pays levies on industrial and municipal discharges could internalize

environmental costs while generating local revenue. Payment for Ecosystem Services (PES) schemes would compensate upstream communities for maintaining forest cover and watershed integrity that benefit downstream water users. Additionally, green and blue bonds could mobilize private capital for sanitation, wastewater treatment, and clean energy investments.

- **Climate Finance Opportunities**: The Lake Victoria Basin (LVB) is well positioned to access a growing range of international climate finance instruments due to its high vulnerability to climate change, strong transboundary framing, and clear links to global mitigation and adaptation priorities. Key windows include the Green Climate Fund (GCF), Adaptation Fund, Global Environment Facility (GEF), and Climate Investment Funds (CIF), alongside bilateral climate finance from development partners. Priority investment areas include climate-resilient water infrastructure, flood and drought risk management, watershed and wetland restoration, climate-smart agriculture, clean energy transitions, and pollution control. The LVBC provide a strong platform for programmatic, multi-country proposals, which are increasingly favored by climate funds seeking scalability and systemic impact. Blended finance models that combine grants, concessional loans, and private capital offer additional opportunities, particularly for sanitation, renewable energy, agro-processing, and eco-tourism.

Table 8-2. *Assessment of Sustainable Financing Mechanisms for Transboundary Cooperation*

Financing Mechanism	Description	Example RBOs	Applicability/Considerations for LVBC
Member State Contributions - Equal Shares	All member states contribute an equal amount to the core budget, promoting a sense of shared ownership and simplicity.	LVBC, ORASECOM, ZAMCOM (GIZ, 2014)	Current model for LVBC. Simple but does not account for differences in economic capacity or benefits derived from the basin.
Member State Contributions - Key-Based	Contributions are based on an agreed formula (e.g., GDP, population in basin, water use), reflecting principles of equity or benefit distribution.	CICOS, NBA (GIZ, 2014)	Potentially more equitable but requires complex negotiations to agree on the key. Could increase contributions from larger economies.
Polluter-Pays Levies	Fees are charged to municipalities and industries based on the volume and toxicity of their effluent discharges. Revenue is ring-fenced for water quality management.	Widely used in European basins (e.g., Danube) (GIZ, 2014)	High potential for generating sustainable revenue for pollution control. Requires strong national enforcement capacity and political will to implement.
Payment for Ecosystem Services (PES)	Downstream beneficiaries (e.g., hydropower companies, water utilities) pay upstream land users for conservation practices that maintain water quality and flow.	Various national schemes; potential in Mara River Basin (Chapter 3.)	Could finance catchment restoration. Requires clear scientific links between land use and water services, and robust institutional arrangements.

Financing Mechanism	Description	Example RBOs	Applicability/Considerations for LVBC
Blended Finance / Green & Blue Bonds	Combining public/concessional funds with private capital to finance large-scale, revenue-generating projects (e.g., wastewater treatment, sustainable aquaculture).	Global trend; explored by Uganda (SoBR, n.d.; World Bank, n.d.-a; World Bank, n.d.-b)	Essential for closing the large infrastructure financing gap (e.g., LWIS). Requires a pipeline of bankable projects and a stable investment climate.
Regional Trust Funds	An independent endowment or sinking fund capitalized by donors, governments, and private sources. Provides a stable, long-term source of funding for core costs and projects.	NBI Trust Fund (GIZ, 2014)	Could provide a buffer against donor funding cycles and ensure continuity of critical functions like monitoring and coordination. Requires significant initial capitalization.

Together, the above instruments would create a hybrid financing model that combines domestic resources, private investment, and targeted donor support—ensuring continuity, ownership, and long-term financial resilience.

8.9.2 Human Capacity Development and Water Diplomacy

Sustained institutional performance depends on qualified and motivated personnel across all governance levels. Regional and national institutions require targeted training in areas such as Integrated Water Resources Management (IWRM), hydrological and water-quality monitoring, GIS and data analytics, climate modeling, project finance, and monitoring and evaluation. Strengthening professional exchange programs among Partner States could enhance technical harmonization and peer learning.

Equally critical is the development of ***Water Diplomacy*** skills. Managing a shared basin involves negotiation, mediation, and benefit-sharing as much as technical expertise. Capacity-building in transboundary negotiation, conflict resolution, and joint planning is vital for managing the political sensitivities associated with shared water resources. Given the sovereignty–integration dynamics noted throughout this report, these soft skills are as essential as engineering or scientific expertise for building mutual trust and sustaining cooperative action.

8.10 Conclusions and Recommendations

8.10.1 Key Findings Summary

Table 8-3. Water Governance Scorecard

GOVERNANCE DIMENSION	STATUS	KEY FINDINGS
1. Legal & Institutional Framework		Comprehensive regional protocols and national laws exist. Lake Victoria Basin Commission Act (2022) provides legal autonomy. However, Protocol on Environment and Natural Resources (2006) not fully ratified. Implementation gaps between frameworks and practice.
2. Regional Coordination (LVBC/LVFO)		Strong strategic and technical competence in planning, monitoring platforms, and financing mobilization. However, chronic understaffing, limited operational depth, and weak authority to enforce national implementation. Heavy donor dependence undermines continuity.
3. National Implementation Capacity		Adequate legal frameworks but weak enforcement at catchment and local levels. Significant asymmetries among Partner States. Limited technical expertise, staffing, and financial resources. Monitoring and regulatory enforcement are severely under-resourced.
4. Financial Sustainability		Critical structural constraint. Heavy dependence on short-term donor projects. Irregular Partner State contributions. Absence of stable, predictable domestic financing weakens institutional continuity and long-term planning. Core functions at risk after project cycles.
5. Framework-Function Dichotomy		Major gap between well-developed governance frameworks and practical execution. Sophisticated policies exist but lack implementation pathways, adequate resourcing, or enforceable accountability. Regional standards remain largely on paper.
6. Monitoring & Data Systems		Regional hydro-meteorological system operational with 60+ stations. However, fragmented networks, persistent data silos, uneven national reporting, and limited groundwater/ecosystem data. Inadequate integration into policy decisions.
7. Stakeholder Participation		Expanded involvement of civil society, WRUAs, BMUs, and private sector. However, engagement remains uneven and weakly institutionalized. Most participation driven by external projects rather than permanent mechanisms. Post-project sustainability challenges.
8. Enforcement & Accountability		Weak accountability mechanisms. Partner States can sign agreements without ensuring implementation, facing few consequences. LVBC lacks enforcement authority. Limited compliance monitoring. IUU fishing and pollution violations widespread despite regulations.

GOVERNANCE DIMENSION	STATUS	KEY FINDINGS
9. Transboundary Cooperation & Trust		Strong foundation built on shared heritage, common language, and historical cooperation. Water hyacinth success demonstrated joint action benefits. Political trust improving through sustained dialogue.
10. Knowledge Systems & Research		Regional research collaboration advancing but translation into policy remains uneven. Lake Victoria Research Initiative active. Proposed LVBC Centre of Excellence could strengthen science-policy interface. Public awareness initiatives emerging but need expansion.
11. Climate Finance & Innovation		Basin well-positioned for GCF, Adaptation Fund, and GEF access. NCCR programme demonstrates climate integration. However, limited capacity for developing bankable projects. Need for innovative financing mechanisms (trust funds, PES, green bonds) not yet established.
12. Private Sector Engagement		Emerging through EPSGG project promoting RECP practices. East African Business Council supporting sustainability integration. Public-private partnerships advancing in sanitation. However, bankability challenges and regulatory uncertainty remain constraints.

Traffic Light Legend

COLOUR	MEANING
	STRONG: Well-functioning with good performance
	MODERATE: Functional but with significant gaps or constraints
	WEAK: Critical challenges requiring urgent attention

Notable Achievements

The Lake Victoria Basin stands as one of Africa's leading examples of regional cooperation in shared resource management. Over two decades, Partner States have constructed a sophisticated architecture of legal frameworks, institutional arrangements, and technical programs. The successful control of water hyacinth, establishment of regional hydro-meteorological monitoring system with 60+ real-time stations; development of harmonized regional standards for water quality, fisheries, and environmental monitoring, and successful implementation of flagship infrastructure programmes (LVEMP, LVWATSAN, LVB-IWRM) demonstrate what cooperative action can achieve.

Cooperation has contributed to peace and stability, supported economic integration, and built trust among Partner States. The entry into force of the Nile CFA in 2024 provides new momentum and opportunities. The basin's governance model has evolved from conflict avoidance to active collaboration, with institutions like LVBC and programs like NCCR demonstrating effective joint delivery. Bilateral cooperation mechanisms (Mara River, SMM Basin MoUs) demonstrate the success of joint sub-basin management.

Critical Systemic Weaknesses

Yet significant challenges persist. The framework-function gap identified throughout this chapter reflects structural and capacity limitations rather than deliberate design flaws.

Despite world-class policies and agreements, implementation remains uneven and under-resourced. Implementation is disconnected from policy design. Water quality continues to deteriorate, invasive species resurge periodically, and pollution loads overwhelm treatment capacity.

Financial sustainability remains elusive, with heavy donor dependence creating vulnerabilities. Core functions (monitoring, enforcement, coordination) lapse after project cycles. Irregular Partner State contributions undermine predictability and long-term planning. Institutional capacities vary widely among Partner States, hindering harmonized action. Coordination between regional, national, and local levels remains weak. Water management intersects with agriculture, energy, transport, health, and environment, but cross-sectoral coordination mechanisms remain weak. Sectoral ministries pursue separate agendas with limited integration. Stakeholder participation, while improving, does not consistently translate into policy influence. Accountability mechanisms lack teeth, allowing commitments to go unfulfilled without consequences.

There are persistent data silos, uneven national reporting, and limited integration of scientific research into policy. Early warning systems and evidence-based governance are undermined by poor information flows.

The Framework-Function Gap Revisited

The central insight from this analysis is that the basin's challenges stem not from inadequate frameworks but from insufficient implementation capacity, resources, and political follow-through. Bridging this gap requires not new policies or institutions but rather operational empowerment of existing ones. The architecture is largely in place; what is needed is activation, resources, and sustained commitment to transform cooperation from an aspirational framework into an effective system of governance.

8.10.2 Strategic Recommendations

For Partner States

Strengthen Political Commitment: Elevate water governance to high-level political attention, ensuring commitments made at Ministerial levels translate into budgetary allocations and implementation

- **Increase Financial Contributions:** Commit to predictable, adequate annual contributions to LVBC and national water institutions as percentage of national budgets
- **Harmonize and Enforce**: Accelerate harmonization of national laws and standards with regional frameworks, and strengthen enforcement capacity at all levels
- **Integrate Planning**: Mainstream basin considerations into national development plans, sector strategies, and investment frameworks
- **Build Capacity**: Invest in technical capacity at national and local levels, including training, equipment, and institutional strengthening

For LVBC and Regional Institutions

For the LVBC and regional institutions, the priority is to shift from policy to results through stronger implementation support, coordinated monitoring, meaningful stakeholder engagement, and strategic positioning within the emerging NRBC framework.

- **Focus on Implementation**: Shift emphasis from policy development to implementation support, providing technical assistance to Partner States for translating agreements into action.
- **Strengthen Monitoring**: Expand and sustain environmental monitoring networks, ensuring data quality and timely dissemination for evidence-based decision-making.

- **Democratise Access to Basin Data for Decision-Making:** Operationalise last-mile access to the LVB Water Information System (LVB-WIS) through simplified community dashboards, mobile-access platforms, and formal data-sharing protocols with WRUAs/WUAs and local governments, to correct data asymmetries and enable evidence-based grassroots participation.
- **Enhance Coordination:** Strengthen coordination mechanisms with NBI/NRBC, national governments, and sub-basin organizations to ensure coherence and avoid duplication.
- **Engage Stakeholders**: Deepen stakeholder engagement beyond consultative forums to meaningful participation in decision-making, resource allocation, and accountability.
- **Demonstrate Results**: Prioritize visible, tangible achievements that demonstrate the value of cooperation, building political support and public confidence.
- **Prepare for NRBC**: Proactively engage with NRBC establishment to secure clear functional division and subsidiary arrangement for LVB management.

For development partners, the priority is to move from fragmented projects to long-term, harmonized institutional support that strengthens core capacities, enables financial sustainability, fosters South–South learning, and aligns financing with regional and national priorities.

- **Provide Institutional Support**: Shift from project-based funding to institutional budget support that strengthens core LVBC and national institution capacity.
- **Harmonize Approaches**: Align donor support with Partner State priorities and regional frameworks, avoiding fragmentation and parallel systems.
- **Support Financial Sustainability**: Help establish innovative financing mechanisms including PES schemes, basin development funds, and climate finance access.
- **Enable South-South Learning**: Facilitate knowledge exchange with other successful transboundary basin organizations.
- **Maintain Long-term Engagement:** Environmental management requires sustained support beyond typical project cycles; commit to multi-year programmatic engagement.

For Civil Society and Private Sector

For civil society and the private sector, the priority is to strengthen accountability and community action, promote green investment, and complement official systems through citizen-led monitoring and advocacy.

- **Strengthen Advocacy**: Amplify voices demanding accountability for environmental commitments and transparent resource management.
- **Support Community Action**: Invest in community-based organizations (WRUAs, BMUs) that serve as implementation bridges between policy and practice.
- **Promote Social Equity:** Move from gender quotas to "dual-signature" financial systems in BMUs and WRUAs, where at least one signatory on all financial accounts must be a woman, ensuring substantive power-sharing.
- **Promote Green Investment**: Develop sustainable business models that create economic value while supporting environmental objectives.
- **Blue Economy Certification:** Launch a "Lake Victoria Blue Economy Seal" through the EABC to certify industries and agri-businesses that meet RECP standards, creating a market-based incentive for compliance.
- **Enhance Monitoring**: Complement official monitoring through citizen science, community-based monitoring, and watchdog functions.

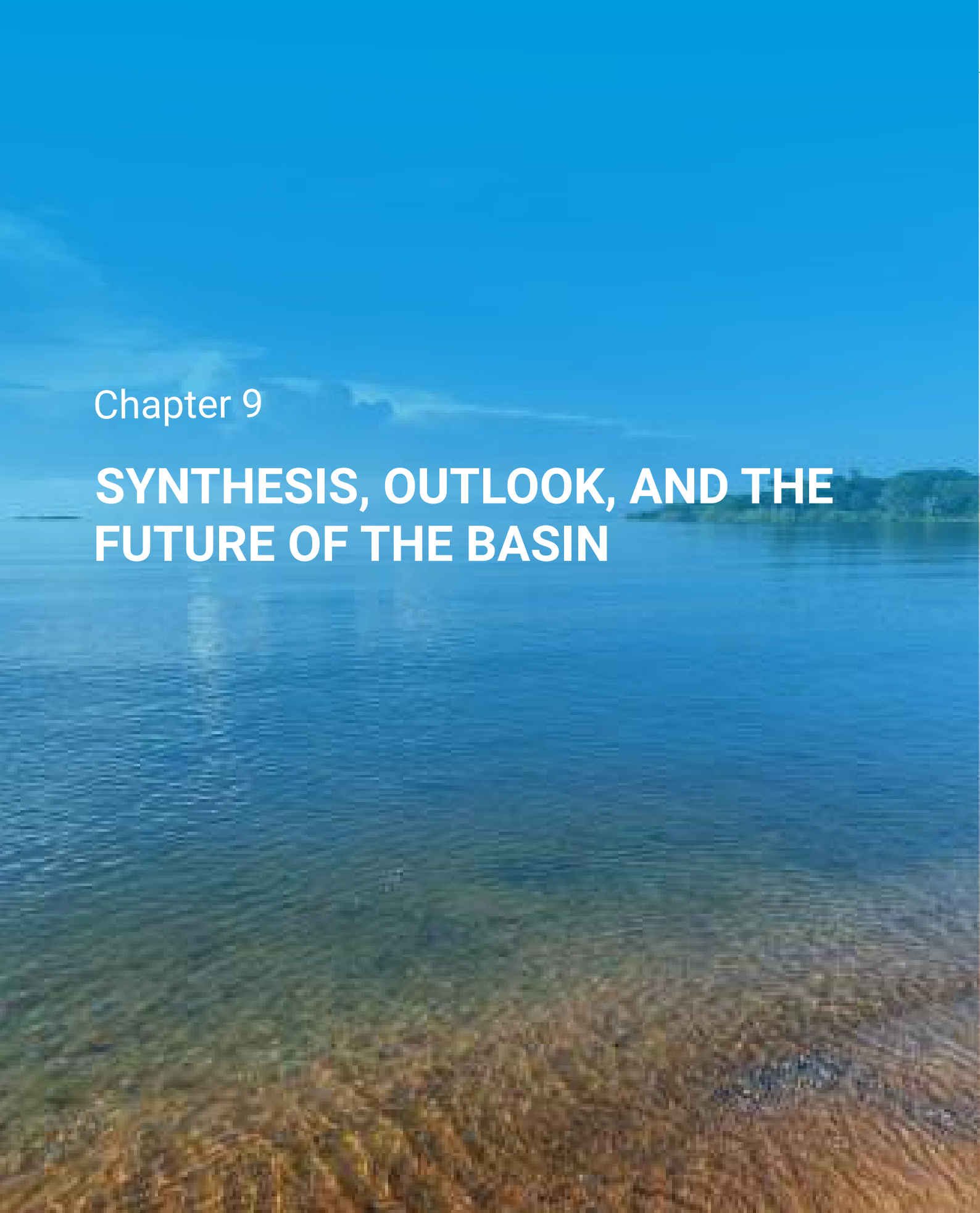
8.10.3 Pathways from Framework to Function

The central challenge for Lake Victoria Basin governance is no longer the absence of legal or institutional frameworks, but the persistent gap between formal mandates and functional delivery. Moving forward, priority must shift from expanding policy architecture to strengthening the practical conditions that allow existing institutions to perform: predictable financing, professional staffing, operational data systems, and enforceable compliance mechanisms.

At basin scale, the transition toward the Nile River Basin Commission (NRBC) provides an opportunity to clarify subsidiary arrangements, consolidate mandates, and correct long-standing coordination inefficiencies between LVBC, NBI, and national agencies. This transition should be managed as a functional realignment exercise rather than a legal restructuring alone.

Importantly, the sustainability of cooperation will depend on shifting from fragmented project cycles to programmatic, climate-aligned investment that blends public finance, climate funds, and private capital. Embedding stakeholder institutions, digital water information systems, and benefit-sharing mechanisms within this investment logic offers the most credible pathway for converting cooperative frameworks into durable development outcomes.

Success will require patience, persistence, and sustained engagement from all actors—Partner States, regional institutions, development partners, civil society, private sector, and local communities. The challenges are formidable, but the stakes—economic prosperity, environmental sustainability, and regional stability for over 45 million people—demand nothing less than transformative action. The frameworks exist. The knowledge exists. What is needed now is the political will and resource commitment to translate potential into reality.



Chapter 9

SYNTHESIS, OUTLOOK, AND THE FUTURE OF THE BASIN

SUMMARY (CHAPTER 9)

Chapter 9 brings together the key findings of the State of the Basin Report and charts a forward-looking roadmap for the sustainable future of the Lake Victoria Basin (LVB). It situates the basin at a critical turning point—where accelerating population growth, environmental decline, and economic pressures threaten its stability, yet transformative opportunities exist to restore its ecological health and shared prosperity. The chapter synthesizes the major challenges and drivers identified throughout the report, outlines priority investment needs, presents contrasting future scenarios to 2050, and proposes a set of strategic, actionable recommendations. It concludes by emphasizing the importance of ongoing monitoring and accountability to ensure that the basin follows a sustainable and climate-resilient development path.



The Basin at a Defining Turning Point

A regional powerhouse under mounting stress. The Lake Victoria Basin remains East Africa's primary economic, demographic, and ecological engine—contributing nearly 60% of EAC GDP



Priority Investments for a Sustainable Basin Transition

Closing the resilient infrastructure gap is non-negotiable. Large-scale investment in sanitation, wastewater treatment, fecal sludge management, and solid waste systems is the most urgent intervention



Overarching Strategic Recommendations

Move from fragmented projects to a basin-wide transformation agenda. The Lake Victoria Basin requires coordinated, large-scale, and simultaneous investments across infrastructure, ecosystems, livelihoods, and institutions.



Two Divergent Futures

The Sustainable Development scenario: a path to resilience.

The Business-as-Usual scenario: a path to crisis

Key Messages

The Basin at a Defining Turning Point

1. **A regional powerhouse under mounting stress**. The Lake Victoria Basin remains East Africa's primary economic, demographic, and ecological engine—contributing nearly 60% of EAC GDP—yet accelerating environmental degradation, climate volatility, and governance constraints now threaten the very foundations of this productivity.
2. **From abundance to constraint: water quality as the binding limit.** Despite relative water abundance, declining water quality—driven by pollution, eutrophication, and catchment degradation—has emerged as the basin's most immediate and systemic constraint, undermining fisheries, public health, tourism, and water security.
3. **A deepening poverty–environment–climate trap.** Rapid population growth, dependence on climate-sensitive livelihoods, inadequate sanitation, and ecosystem degradation interact with climate change to form a self-reinforcing cycle of vulnerability, inequality, and rising economic losses—especially for women, youth, and informal settlements.

Lessons from the Lake Victoria Basin

4. **Severe challenges have not precluded progress**. Despite intense demographic pressure, environmental degradation, and climate risk, the Lake Victoria Basin has recorded tangible achievements in cooperation, ecosystem protection, water management, and livelihoods.

5. **Shared knowledge has been the strongest foundation for cooperation**. Joint basin-wide assessments, harmonised indicators, and regional monitoring systems have proven to be effective trust-building tools and practical entry points for transboundary collaboration.
6. **Institutions matter more than perfection**. Durable regional coordination platforms and legal frameworks have enabled cooperation and learning even where enforcement capacity, financing, and implementation remain uneven.
7. **Targeted interventions can deliver outsized gains.** Localised ecosystem restoration, pollution control in priority hotspots, and focused climate-risk investments have demonstrated that recovery and risk reduction are achievable when actions are well targeted.
8. **Ecosystem protection and livelihoods can advance together.** Experiences with fisheries co-management, protected areas, and emerging blue-economy activities show that environmental stewardship and economic opportunity are mutually reinforcing.
9. **Climate information saves lives and livelihoods**. Investments in hydro-meteorological monitoring, early warning, and climate-informed operations have reduced disaster impacts and strengthened resilience in a highly climate-sensitive basin.
10. **The basin offers transferable lessons for global transboundary waters.** The Lake Victoria experience demonstrates that shared evidence, pragmatic institutions, and coalition-based delivery can sustain cooperation and progress even in complex, multi-country basins.

Priority Investments for a Sustainable Basin Transition

11. **Closing the resilient infrastructure gap is non-negotiable.** Large-scale investment in sanitation, wastewater treatment, fecal sludge management, and solid waste systems is the most urgent intervention. Full implementation of the USD 1.9 billion Lakewide Inclusive Sanitation (LWIS) Strategy is essential to halt pollution and protect human and ecosystem health.
12. **Restoring natural capital as climate infrastructure.** Reforestation of key water towers, wetland protection and rehabilitation, and sustainable land management are not optional conservation measures but core climate-resilience investments that regulate flows, reduce sediment and nutrient loads, and buffer floods and droughts.
13. **Shifting from extraction to a regenerative blue-green economy** toward sustainable aquaculture, climate-smart agriculture, circular waste systems, renewable energy, and eco-tourism can generate jobs, reduce pressure on ecosystems, and unlock a demographic dividend for the basin's youthful population.

Three Divergent Futures to 2050

14. **The Business-as-Usual scenario: a path to crisis.** If current trends persist, pollution, climate extremes, and ecosystem collapse will intensify—threatening fisheries worth over USD 1 billion annually, displacing tens of millions of people, and locking the basin into escalating humanitarian, fiscal, and environmental costs.
15. **Limited improvement: slowing decline without transformation.** Partial, uneven, and donor-dependent interventions may stabilize conditions in selected hotspots, but without basin-wide scale, predictable financing, and institutional reform, core vulnerabilities will persist and inequities will widen.
16. **The Sustainable Development scenario: a path to resilience.** With coordinated regional action, investment, and innovation, the basin can restore its ecosystems, diversify its economy, and achieve climate-resilient prosperity. The future depends on the choices made today.

Overarching Strategic Recommendations

17. **Move from fragmented projects to a basin-wide transformation agenda**. The Lake Victoria Basin requires coordinated, large-scale, and simultaneous investments across infrastructure, ecosystems, livelihoods, and institutions. Pilot projects and isolated

interventions are no longer sufficient to shift the basin onto a sustainable pathway.

18. **Prioritise climate-resilient infrastructure and natural capital as core development assets.** Closing the sanitation and pollution gap—through full implementation of the Lakewide Inclusive Sanitation (LWIS) Strategy—together with restoring forests, wetlands, and catchments, is the most immediate and cost-effective way to protect water quality, public health, and climate resilience.

19. **Transition the basin's economy toward regenerative, people-centred growth.** Long-term resilience depends on shifting from resource-extractive practices to a regenerative blue and green economy that creates jobs, builds skills, and unlocks the basin's demographic dividend—particularly for youth and women.

20. **Strengthen governance effectiveness and secure sustainable financing.** Advanced regional frameworks exist, but outcomes are constrained by weak enforcement, fragmented mandates, and donor dependence. Closing the framework–function gap and establishing predictable, long-term financing for basin institutions—especially the LVBC—are critical to delivery at scale.

21. **Institutionalise evidence, cooperation, and accountability.** Basin-wide data sharing, strengthened monitoring systems, and a regular five-year State of the Basin reporting cycle—focused on measurable outcomes rather than activities—are essential to guide investment, manage transboundary risks, and sustain political commitment to a shared future.

Accountability, Learning, and the Path Forward

22. **Embedding long-term monitoring and political accountability**. Institutionalizing a regular five-year State of the Basin Report cycle, supported by a balanced indicator framework covering environmental health, socio-economic wellbeing, and governance effectiveness, is essential to sustain momentum, track results, and hold all actors accountable.

23. **The basin's future is a policy choice, not a forecast.** The contrast between crisis and resilience underscores a central message of the chapter: the Lake Victoria Basin's trajectory will be determined by decisions taken now—on investment, cooperation, and governance—not by biophysical limits alone.



Figure 9-1. *A sandy beach on Banda Island, Sse archipelagos, Lake Victoria.*

9.1 A Basin at a Crossroads: A Synthesis of Key Findings

9.1.1 The significance of the Lake Victoria Basin

Despite the serious challenges documented throughout this State of the Basin Report, the Lake Victoria Basin (LVB) remains one of Africa's most naturally endowed, economically dynamic, and strategically significant regions. The basin's scale, diversity, and productive potential position it not only as a region under pressure, but as a cornerstone of East Africa's blue-green development future.

At the heart of the basin lies Lake Victoria itself—the world's largest tropical lake and the second-largest freshwater lake by surface area. Covering approximately 68,800 km² and holding an estimated 2,424 km³ of freshwater, the lake constitutes a strategic natural asset of continental significance (Chapter 2). Its shallow morphology, extensive shoreline of over 3,400 km, and nearly 1,000 islands create highly productive ecological niches that support fisheries, inland navigation, tourism, and dense human settlement (Beadle, 1981; Chapter 2). As the source of the White Nile, Lake Victoria also anchors regional hydrology far beyond the basin, reinforcing its importance within Africa's broader water and energy systems (Sutcliffe & Parks, 1999.

9.1.2 A global centre of biodiversity and ecosystem services

Ecologically, the Lake Victoria Basin represents an exceptional mosaic of interconnected freshwater and terrestrial ecosystems of regional and global importance. The basin is internationally renowned as the site of one of the most rapid evolutionary radiations in vertebrate history—the diversification of over 500 haplochromine cichlid species within the lake over the past ~15,000 years (Johnson et al., 2000; Seehausen, 1996). Although invasive species, eutrophication, and overfishing have altered the lake's food web, satellite lakes, fringing wetlands, and riverine systems continue to serve as critical refugia and genetic reservoirs for native biodiversity (Darwall et al., 2018; Chapter 3).

Beyond the lake itself, the basin encompasses montane forests, savanna–forest mosaics, papyrus wetlands, and volcanic grasslands that deliver ecosystem services worth billions of dollars annually. These services include flood regulation, water purification, carbon sequestration, climate moderation, and cultural heritage values (Millennium Ecosystem Assessment, 2005; LVBC, 2026). Iconic systems such as the Serengeti–Maasai Mara migration landscape, the Mau and Nyungwe–Kibira forest complexes, and extensive papyrus wetlands such as Yala Swamp and Mabamba Bay demonstrate the tight coupling between biodiversity conservation and regional development within the basin (Bell, 1971; Plumptre et al., 2007; Chapter 3).

9.1.3 A highly productive biophysical foundation

The basin's exceptional productivity is rooted in a rare convergence of favourable climate, hydrology, and soils. Located astride the equator, the LVB experiences a relatively stable bimodal rainfall regime driven by interactions between the Inter-Tropical Convergence Zone and the lake's vast thermal mass (Anyah & Semazzi, 2004). Annual rainfall typically ranges from 1,200 mm to over 2,000 mm, while mean temperatures of 24–29°C support year-round biological productivity (Chapter 4). Approximately 80–82% of the lake's inflow derives directly from precipitation over its surface, making Lake Victoria one of the most atmosphere-dependent freshwater systems

globally and a reliable hydrological buffer for surrounding landscapes (Sene & Plinston, 1994; Chapter 4).

Soil diversity further underpins the basin's agricultural strength. Fertile volcanic and highland soils—particularly in areas such as Mt. Elgon, the Mau escarpment, and the Albertine Rift—support globally competitive tea and coffee systems, while alluvial and hydromorphic soils in floodplains and deltas sustain rice cultivation and irrigated agriculture (Lovett & Wasser, 1993; Chapter 6). These conditions have enabled the basin to function as one of East Africa's most important food baskets, with significant scope for climate-resilient intensification through irrigation, soil management, and value addition (African Development Bank, 2016; Chapter 6).

9.1.4 The demographic and economic heart of East Africa

Socio-economically, the Lake Victoria Basin is the demographic and economic core of East Africa. Home to over 45 million people today and projected to exceed 100 million by mid-century, the basin hosts one of the continent's youngest and fastest-growing populations (Chapter 2). This demographic dynamism presents both pressure and opportunity, offering the potential for a substantial demographic dividend if matched with adequate investment in skills, infrastructure, and inclusive institutions (Nunan, 2020).

The basin already underpins livelihoods for millions across multiple sectors. Agriculture employs over 70% of the population and contributes roughly 30% to national GDPs, while the Lake Victoria fishery—one of the world's largest inland fisheries—produces over one million tonnes of fish annually and supports 3–4 million livelihoods through fishing, processing, and trade (Chapter 6). Emerging aquaculture systems, including cage culture and climate-smart technologies, are further expanding the basin's blue-economy potential and employment base (African Centre for Technology Studies, 2025).

9.1.5 Energy, trade, and regional integration

The Lake Victoria Basin is a strategic hub for energy production and regional connectivity. Hydropower generation along the Victoria Nile supplies the backbone of Uganda's electricity system and contributes to regional power pooling under the Eastern Africa Power Pool, enhancing energy security and resilience to climate variability (African Development Bank, 2016; Chapter 6). At the same time, diversification into geothermal, solar, and other renewables within the basin reduces hydrological risk and supports a low-carbon development pathway (Kenya Electricity Generating Company, 2025).

Inland water transport on Lake Victoria is re-emerging as a low-carbon "liquid highway" linking ports, rail corridors, and landlocked economies. Investments in port modernisation, vessels, and maritime safety systems are transforming the lake into a competitive regional transport corridor under the African Continental Free Trade Area, lowering freight costs while supporting millions of livelihoods (African Continental Free Trade Area Secretariat, 2024; Chapter 6).

Tourism further reinforces the basin's economic significance. Combining world-class terrestrial parks, unique lacustrine environments, islands, wetlands, and cultural heritage sites, the basin contributes approximately 10% of regional GDP and 17% of export earnings, with strong potential for growth through sustainable and community-based tourism models (Chapter 6).

9.1.6 Regional Economic Powerhouse: Why the Basin Matters

Taken together, these assets explain why the Lake Victoria Basin contributes nearly 60% of the combined GDP of the East African Community Partner States, making it the region's primary engine of growth, trade, and integration. Its rivers, wetlands, forests, and lake waters continue to generate food, energy, employment, and cultural identity at a scale unmatched elsewhere in East Africa.

This positive endowment is precisely why the basin's current challenges matter so deeply—and why addressing them offers such high returns. The Lake Victoria Basin is not a region in decline; it is a region in transition. With sustained investment, strengthened institutions, and cooperative basin-wide management, its natural capital and human potential can support a resilient, inclusive, and prosperous future for East Africa and beyond (East African Community, 2021; LVBC, 2026).

9.2 Key Challenges Facing the Lake Victoria Basin

This section presents a synthesized overview of the key challenges facing the Lake Victoria Basin, drawing on and integrating the evidence, analyses, and thematic assessments presented across the preceding chapters of the State of the Basin Report (SoBR). Rather than repeating chapter-specific findings, it distils their core messages into a basin-wide diagnosis of the systemic pressures shaping the basin's current condition and future trajectory.

The Lake Victoria Basin faces a complex and intensifying set of interlinked challenges that span environmental degradation, climate change, socio-economic vulnerability, and systemic governance constraints. These challenges do not operate in isolation; rather, they interact across scales and sectors, reinforcing one another and placing the basin at a critical crossroads between escalating risk and transformative opportunity.

- **Environmental degradation and declining water quality** constitute the most immediate and visible threats to the basin's integrity. Accelerated land-use change, deforestation, wetland encroachment, untreated municipal wastewater, industrial effluents, and agricultural runoff have driven sustained deterioration of rivers, nearshore waters, wetlands, groundwater, and Lake Victoria itself. Although tributaries contribute a minority of inflows, they deliver disproportionate loads of nutrients, sediments, pathogens, and contaminants, fuelling eutrophication, harmful algal blooms, invasive species proliferation, and the expansion of hypoxic "dead zones." Water quality has consequently emerged as the basin's binding constraint on water security, undermining fisheries, drinking-water supply, tourism, and public health, even where water quantities remain relatively abundant (Chapter 3 and Chapter 5).
- **Climate change now acts as a powerful risk multiplier**, amplifying existing stresses and introducing new dimensions of uncertainty. The basin has warmed rapidly—at rates slightly exceeding global averages—while rainfall reliability has declined despite modest increases in annual totals. Rainfall is increasingly concentrated into short, intense events separated by longer dry spells, producing a regime of heightened hydrological volatility. The basin now experiences major floods and droughts one to two times per year—approximately three times the frequency observed in the mid-20th century. These extremes have driven record lake-level fluctuations, widespread displacement, infrastructure damage, and mounting economic losses, while simultaneously stressing groundwater systems, water quality, ecosystems, and hydropower reliability. Projected future warming and intensification of extremes indicate that these pressures will deepen, locking climate risk into

the basin's development trajectory (Chapter 7).

- **High socio-economic vulnerability compounds biophysical stress**, particularly given the basin's heavy reliance on climate-sensitive livelihoods. Rain-fed agriculture, inland fisheries, pastoralism, and hydropower remain central to food security, employment, and income for over 45 million people, yet all are increasingly exposed to climatic shocks, ecosystem degradation, and pollution. Persistent deficits in sanitation and solid-waste management—especially in rapidly growing urban centres, informal settlements, and fishing communities—reinforce pollution pathways and disease burdens. Climate impacts disproportionately affect women, youth, and marginalized groups, while repeated shocks drive internal migration toward lakeshore and urban areas, intensifying pressure on services, infrastructure, and governance systems (Chapter 2 and Chapter 6).
- **Despite a dense and sophisticated institutional architecture,** governance effectiveness remains constrained by a persistent framework–function gap. The Lake Victoria Basin is governed by one of Africa's most advanced transboundary water governance frameworks, embedded within the East African Community and the wider Nile Basin system. The entry into force of the Nile River Basin Cooperative Framework Agreement in 2024 represents a historic legal milestone, reinforcing principles of equitable utilization, benefit sharing, and cooperation. However, practical outcomes remain limited by uneven national capacities, fragmented mandates, weak enforcement, and tensions between national sovereignty and collective regional action. The Lake Victoria Basin Commission has consolidated its coordinating role but continues to face constraints in enforcement authority, predictable financing, and operational scale-up (Chapter 8),
- **Financial sustainability is the most binding structural constraint across all sectors and governance levels.** Core basin functions—monitoring, laboratories, data systems, coordination, compliance, and early warning—remain heavily dependent on short-term, project-based donor financing. The absence of stable, predictable domestic and regional financing mechanisms undermines institutional continuity, long-term planning, and the ability to scale successful pilots into basin-wide solutions. Climate adaptation financing needs alone exceed available flows by a wide margin, creating a growing mismatch between risk exposure and response capacity (Chapter 8).
- **Weak and fragmented knowledge systems further limit adaptive capacity.** Although regional hydrometeorological, water-quality, and environmental monitoring systems exist, they remain uneven, under-resourced, and poorly integrated across countries and sectors. Persistent data silos, gaps in groundwater and ecosystem monitoring, limited downscaled climate information, and weak translation of scientific evidence into policy and operational decisions constrain early warning, climate-risk-informed planning, and accountability. Decisions increasingly outpace data, heightening the risk of maladaptation and inefficient investment Taken together, these challenges reveal a basin under growing stress not because of a lack of legal frameworks, strategic visions, or technical solutions, but because of limitations in implementation capacity, financing, coordination, and resilience-oriented planning. Without a decisive shift toward integrated, climate-informed, and financially sustainable basin management—linking environmental protection with inclusive socio-economic development—the Lake Victoria Basin risks becoming locked into a cycle of escalating degradation, rising costs, and declining resilience.

9.3 Achievements, Good Practices, and Transferable Lessons from the Lake Victoria Basin

The preceding section (Section 9.2) has outlined the significant and interlinked challenges facing the Lake Victoria Basin. However, an exclusive focus on constraints would provide an incomplete and ultimately misleading picture. Despite mounting demographic, environmental, climatic, and governance pressures, the Lake Victoria Basin has also registered **important successes, good practices, and positive lessons** over recent decades. These experiences demonstrate that progress is possible even in large, complex, and highly stressed transboundary systems.

This section synthesizes lessons emerging from across all chapters of the State of the Basin Report (SoBR), highlighting approaches that have delivered tangible results, created enabling conditions for cooperation, or generated valuable learning—even where outcomes remain partial or uneven. Taken together, these experiences offer **practical insights not only for the Lake Victoria Basin itself, but also for other transboundary basins worldwide** that face similar challenges of scale, diversity, and shared sovereignty.

9.3.1 Ecosystem Protection, Restoration, and Biodiversity Refugia

- Key upper-catchment forest systems (e.g., Mau Forest Complex, Mt. Elgon, Nyungwe–Kibira) have remained largely intact or have been partially restored, continuing to regulate flows and sediment loads into Lake Victoria from establishment and enforcement of protected areas.
- Other protected areas within the basin (e.g., Serengeti–Mara, Lake Mburo, Akagera) have continued to function as biodiversity refugia and hydrological buffers, even as pressure on surrounding landscapes intensified.
- Wetland systems such as Mabamba Bay (Uganda) and parts of Yala Swamp (Kenya) have demonstrated localized ecological recovery where protection and controlled use were enforced.
- Satellite lakes and riverine wetlands (e.g., Lake Nabugabo) have preserved remnant native fish populations, acting as genetic refuges after biodiversity loss in the main lake.

Transferable lesson: *Even in heavily degraded basins, strategic protection and partial restoration can preserve critical ecosystem functions and provide recovery nuclei.*

9.3.2 Basin Monitoring, Early Warning, and Climate Risk Management

- A jointly agreed, basin-wide State of the Basin Report was produced for the first time, establishing a shared analytical baseline across all five Partner States and demonstrating that consensus on indicators, data interpretation, and basin priorities is achievable in a complex transboundary context.
- A common set of basin indicators and assessment methodologies was validated by Partner States, enabling comparability across countries while respecting national data ownership—an important precedent for cooperative monitoring in shared basins.
- A regional hydro-meteorological monitoring network has been established, with over 60 operational stations transmitting real-time data to regional and national institutions.
- Flood early-warning systems have been implemented in flood-prone sub-basins (e.g.,

Nyando, Nzoia, Kagera), reducing loss of life and improving disaster preparedness.

- Lake-level and inflow monitoring have informed adaptive hydropower operations along the Victoria Nile, particularly during the 2019–2020 high-water event.
- Climate information has been incorporated into water infrastructure planning in Uganda, Kenya, and Tanzania, improving design robustness under increasing variability.

Transferable lesson: *Shared climate and hydrological information systems are among the highest-return investments in climate-sensitive transboundary basins.*

9.3.3 Water Quality Management and Pollution Control

- Localized improvements in offshore water quality were observed following wastewater treatment upgrades in cities such as Kampala and Kisumu.
- Constructed and natural wetlands were successfully used as nutrient buffers in selected catchments, reducing pollutant loads entering nearshore waters.
- Harmful algal bloom risks have reduced in some open-lake areas, demonstrating that eutrophication pressures can be partially reversed when inputs decline, and under supporting climate conditions.

Transferable lesson: *Water quality recovery is possible when interventions focus first on dominant point sources and leverage natural treatment systems.*

9.3.4 Livelihoods, Resource Co-Management, and the Blue Economy

- Beach Management Units (BMUs) have improved compliance and local stewardship in fisheries where enforcement authority and resources were sustained.
- Inland water transport safety has improved markedly following implementation of the Multinational Lake Victoria Maritime Communications and Transport (MLVMCT) Project, including new aids to navigation and rescue coordination centres in Mwanza, Kisumu, and Entebbe.
- Aquaculture has expanded in Kenya, Tanznia and Uganda, reducing pressure on capture fisheries and diversifying income sources.
- Tourism linked to lake, island, and wetland ecosystems has generated significant employment, particularly in Tanzania and Uganda.

Transferable lesson: *Sustainable livelihoods and ecosystem protection are mutually reinforcing when users are empowered and supported by credible institutions.*

9.3.5 Governance, Legal Frameworks, and Regional Integration

- The Lake Victoria Basin Commission (LVBC) has been operationalised as a recognised regional coordination platform, successfully convening Partner States, sector institutions, and development partners around basin-wide priorities.
- Multi-partner investment platforms were successfully deployed, combining regional institutions, development banks, and climate funds for navigation safety, climate resilience, and ecosystem management.
- Formal cooperation between the LVBC and Nile Basin Initiative (NBI/NELSAP) has been institutionalised, reducing duplication and enabling complementary investment planning in shared sub-basins such as the Kagera and Mara.

Transferable lesson: *Shared assessments and permanent coordination platforms, when anchored in durable legal frameworks and supported by coalition-based delivery models, are powerful trust-building instruments that can sustain transboundary cooperation beyond individual projects and often precede—rather than follow—full regulatory integration.*

9.3.6 Synthesis: Lessons for Transboundary Basins Globally

Taken together, these achievements demonstrate that **the Lake Victoria Basin is not defined solely by its challenges**. Even under intense demographic pressure, environmental stress, and climate risk, the basin has generated practical solutions, institutional innovations, and recovery pathways with relevance far beyond East Africa.

For other transboundary basins, the Lake Victoria experience underscores several key lessons:

- Start with **shared evidence**, not contested claims;
- Invest early in **regional institutions that convene rather than command**;
- Protect and restore **strategic ecological assets** with basin-wide benefits;
- Use **climate and water information as a unifying platform for cooperation**; and
- Frame shared waters as **engines of development and integration**, not merely sources of conflict.

The central message of this section is therefore one of **grounded optimism**. The Lake Victoria Basin shows that while transboundary water challenges are complex and persistent, **success is possible, learning is cumulative, and progress can be scaled** when cooperation, evidence, and long-term vision are aligned.

9.4 Priority Investment Needs and Opportunities

Shifting the basin onto a sustainable pathway requires strategic, large-scale investment in three critical areas: resilient infrastructure, ecosystem restoration, and innovation for a regenerative economy. These should not be viewed as costs, but as essential investments in the basin's natural and human capital.

The most urgent priority is closing the resilient infrastructure gap, particularly in sanitation. The **Lakewide Inclusive Sanitation (LWIS) Strategy**, developed with the World Bank, identifies an investment need of approximately **$1.9 billion** to address the dominant sources of lake pollution: untreated wastewater, fecal sludge, and solid waste from over 100 urban centers around the lake (Chapter 5; World Bank, 2025b). This investment is fundamental to arresting eutrophication and protecting public health. Other critical infrastructure needs include integrated multimodal transport to unlock the basin's trade potential and decentralized clean energy to power rural development and reduce biomass-driven deforestation (Chapter 2).

Investment is also required for large-scale ecosystem restoration. This includes targeted programs for reforestation of degraded catchments and "water towers" like Mount Elgon, rehabilitation of critical wetlands that serve as natural filters and biodiversity refugia, and the promotion of sustainable land management practices to reduce soil erosion and agricultural runoff (Chapter 3; Söderström, 2006).

Finally, investment is needed to foster innovation and transition the basin from a resource-extractive model to a **regenerative blue and green economy**. This involves supporting the growth of sustainable aquaculture to reduce pressure on wild fish stocks, developing value-addition for fisheries byproducts (such as processing Nile perch maws and frames, which can triple revenues), promoting ecotourism that provides non-extractive livelihoods, and scaling up climate-smart agriculture (Chapter 3; Aura et al., 2022). Such investments hold the key to creating sustainable jobs for the basin's youthful population—its greatest potential asset—and breaking the poverty-environment cycle.

9.5 Scenarios for the Future

The choices made today will determine the basin's trajectory for decades to come. To make these choices clear, two contrasting scenarios for the future to 2050 are presented, based on current trends and scientific projections.

9.5.1 The "Business-as-Usual" Scenario

If current trends of population growth, unplanned urbanization, and resource degradation continue without a significant increase in investment and management effectiveness, the basin faces a future of deepening crisis. The population is projected to double by 2050, placing immense pressure on already strained land and water resources (Chapter 2). Unchecked pollution from cities and agriculture will accelerate the eutrophication of Lake Victoria, leading to more frequent and severe algal blooms, expanding anoxic "dead zones," and the potential collapse of key fish stocks, threatening a **US$1.12 billion** industry and millions of livelihoods (Chapter 5; UNEP, 2017).

These pressures will be amplified by climate change. Projections for the basin indicate a mean annual temperature increase of **1.3–4.5°C** and more frequent and intense extreme rainfall events by the end of the century (Chapter 7; Olaka et al., 2019). This will destabilize hydrology, increase flood and landslide risks, and exacerbate water-borne diseases. The compounded effects of resource degradation and climate shocks could lead to widespread food insecurity and the internal displacement of up to **38.5 million people** across the five Partner States by 2050 (Chapter 7). This scenario is a trajectory of irreversible ecological decline, mounting economic losses, and profound social instability.

9.5.2 The "Limited Improvement – Slowing the Decline " Scenario

In this pathway, some progress is made. Investments focus on selected priority areas—such as improving sanitation in a few towns, restoring a handful of catchments, or strengthening pollution control in certain hotspots. Cooperation improves in places, and environmental decline slows locally.

However, action remains **uneven and insufficient**. Many interventions stay at pilot scale and depend heavily on external funding. Pollution is reduced in some areas but continues elsewhere, and benefits are not shared equally among countries or communities.

By 2050, the basin avoids total collapse, but many problems persist. Water quality stabilises in parts of the lake, yet health risks, climate impacts, and livelihood insecurity continue to affect millions of people. This pathway **buys time**, but it does not fully address the root causes of degradation.

9.5.3 The "Sustainable, Climate-Resilient Development" Scenario

A third alternative future is possible. This scenario envisions the outcomes of a concerted, transboundary effort to implement the strategic recommendations of this report. In this future, the full implementation of the LWIS strategy and other pollution control measures has significantly reduced nutrient loading, leading to improved water quality and a healthier lake ecosystem. Fisheries are managed sustainably, supported by a thriving aquaculture sector, safeguarding both biodiversity and economic returns.

Restored forests and wetlands regulate water flows, reduce erosion, and enhance climate resilience. Widespread adoption of climate-smart agriculture has boosted food security and farmer incomes. A vibrant green and blue economy, centered on ecotourism, renewable energy, and a circular economy for waste, provides sustainable jobs and opportunities for youth and women. In this scenario, the Lake Victoria Basin has successfully broken the poverty-environment trap and transformed itself into an engine of resilience and shared prosperity for the entire East African Community.

The stark contrast between the three futures underscores the urgency of the present moment. The "Business-as-Usual" and "Partial Improvement" scenarios are not merely a scientific projection; they are a narrative of profound risk that highlights the high cost of inaction or little action. The "**Sustainable Development**" scenario is a narrative of opportunity. Presenting these scenarios is a strategic tool designed to mobilize the political will and large-scale investment required to choose the sustainable pathway. A resilient and prosperous future for the basin is an achievable choice, not an inevitability.

9.6 Overarching Strategic Recommendations

To navigate the basin from its current crossroads to the sustainable development pathway, this report synthesizes its findings into a prioritized action plan. The recommendations are grouped under three core strategic pillars and organized by timeframe to provide a practical roadmap for implementation, aligned with the LVB IWRMD Strategy (2023-2050).

Table 9-1. Prioritized Strategic Recommendations for a Sustainable Basin

Strategic Pathway	Specific Recommendation	Key Responsible Actors	Timeframe
1. Build and Maintain Climate-Resilient Infrastructure	1.1 Secure and mobilize the required $1.9 billion for full implementation of the Lakewide Inclusive Sanitation (LWIS) Strategy, prioritizing wastewater treatment plants, sewer networks, safe toilets, and solid waste management in the 100+ towns and cities around the lake.	EAC, LVBC, Partner States (Ministries of Finance, Water), World Bank, AfDB, other IFIs	Short-Term
	1.2 Invest in stormwater management and drainage systems in urban areas to reduce flooding and pollution flowing into the lake.	Partner States (Ministries of Water, Local Government), Development Partners	Medium-Term
	1.3 Ensure functioning and regular maintenance of existing monitoring equipment, sewage treatment facilities, and environmental infrastructure to deliver tangible results on the ground.	Partner States (Ministries of Water, Environment, Local Government)	Short-Term
	1.4 Develop and implement an integrated, multimodal transport master plan linking road, rail, and lake transport to enhance regional trade.	EAC, Partner States (Ministries of Transport, Infrastructure)	Medium-Term

Strategic Pathway	Specific Recommendation	Key Responsible Actors	Timeframe
	1.5 Accelerate investment in decentralized renewable energy systems (e.g., mini-grids, off-grid solar, small hydropower, wind) to expand energy access in rural areas and reduce pressure on forests.	Partner States (Ministries of Energy), Private Sector, Development Partners	Medium-Term
	1.6 Mandate climate-risk screening and "climate-proofing" for all new major infrastructure projects (roads, ports, power systems, water infrastructure) to withstand floods, droughts, and extreme weather.	EAC, Partner States (National Planning Authorities, NEMAs)	Short-Term
2. Restore Natural Capital and Promote Sustainable Production	2.1 Invest in large-scale reforestation of key "water tower" areas (Mount Elgon, Mau Forest) and protect remaining forest cover to regulate rainfall, reduce erosion, and maintain river flows.	Partner States (Ministries of Environment, Forestry), LVBC, Development Partners	Medium-Term
	2.2 Restore and protect critical wetlands to filter pollution, reduce sedimentation, mitigate floods, and strengthen climate resilience before water reaches the lake.	Partner States (Ministries of Environment, Water), Local Governments, Communities	Short-Term
	2.3 Promote and finance adoption of climate-smart agricultural practices (soil conservation, agroforestry, efficient irrigation, responsible fertilizer use) to reduce erosion, nutrient runoff, and water pollution while increasing farm productivity.	Partner States (Ministries of Agriculture), Development Partners, Private Sector	Medium-Term
	2.4 Invest in sustainable aquaculture (well-regulated cages and ponds) and improve fish processing to reduce post-harvest losses and pressure on wild fish stocks.	LVFO, Partner States (Fisheries Departments), Private Sector, Development Partners	Short-Term
	2.5 Promote private sector investment in clean technologies, pollution prevention, circular economy solutions, and green enterprises through incentives, regulations, and public-private partnerships.	Partner States (Ministries of Trade, Environment), EAC, Private Sector	Medium-Term

Strategic Pathway	Specific Recommendation	Key Responsible Actors	Timeframe
3. Strengthen Governance, Institutions, and Accountability	3.1 Ratify and domesticate outstanding regional legal instruments, particularly the EAC Protocol on Environment and Natural Resources Management.	Partner States (Parliaments, Ministries of Foreign Affairs)	Short-Term
	3.2 Establish a sustainable financing mechanism for the LVBC (e.g., a regional Trust Fund) to reduce donor dependency, ensure long-term operational capacity, and enable predictable funding through increased national budget contributions.	EAC Council of Ministers, LVBC, Partner States (Ministries of Finance)	Medium-Term
	3.3 Scale up enforcement of environmental regulations, including prosecuting illegal wetland encroachment, deforestation, and pollution violations, with dedicated resources for inspection and compliance monitoring.	Partner States (NEMAs, Attorney General's Offices, Judiciary), LVBC	Short-Term
	3.4 Develop and adopt a regional data-sharing protocol, guideline, or other suitable instrument to fully operationalize the LVB-WIS, harmonize data formats and quality control standards, automate near-real-time sharing, and integrate satellite Earth observation with ground-based monitoring.	LVBC, Partner States	Short-Term
	3.5 Densify water resources monitoring networks in data-poor headwater areas (especially Burundi), expand open-lake meteorology stations, and enhance sediment and real-time water quality monitoring capacity.	LVBC, Partner States (Ministries of Water, Environment), Development Partners	Short-Term
	3.6 Formalize and empower national and regional cross-sectoral coordination platforms to ensure water, energy, food, and environmental policies are aligned.	EAC, Partner States (President's/Prime Minister's Offices)	Medium-Term

Strategic Pathway	Specific Recommendation	Key Responsible Actors	Timeframe
	3.7 Strengthen the legal mandates, authority, training, and provide dedicated funding streams for local co-management institutions (BMUs, WRUAs) and ensure meaningful engagement of civil society organizations.	Partner States (Ministries of Water, Fisheries, Local Government)	Medium-Term
	3.8 Establish transparent monitoring and reporting mechanisms to track implementation progress based on measurable outcomes (cleaner water, healthier fish stocks, improved livelihoods) rather than reports produced.	LVBC, Partner States	Short-Term
	3.9 Strengthen enforcement of fishing regulations and ensure compliance with fisheries management measures.	LVFO, Partner States (Fisheries Departments), BMUs	Short-Term
4. Invest in People and Green-Blue Economy Livelihoods	4.1 Develop and fund vocational training programs focused on green and blue economy skills (sustainable aquaculture, ecotourism, renewable energy, solar installation, environmental services).	Partner States (Ministries of Education, Labour), Private Sector, Development Partners	Short-Term
	4.2 Establish financial mechanisms (e.g., concessional credit lines, venture capital funds) to support youth- and women-led enterprises in green and blue economy sectors.	Partner States (Ministries of Finance), EAC, Development Banks, Private Sector	Medium-Term
	4.3 Scale up investment in value-addition for agricultural and fishery products to increase local incomes and reduce post-harvest losses.	LVFO, Partner States (Ministries of Trade, Agriculture, Fisheries), Private Sector	Medium-Term
	4.4 Support livelihood diversification through investments in eco-tourism, clean lake transport, recycling, waste-to-energy, and sustainable aquaculture that generate income while protecting the environment.	Partner States, Private Sector, Development Partners	Medium-Term
	4.5 Integrate climate education and sustainable resource management principles into national school curricula.	Partner States (Ministries of Education)	Long-Term

9.7 Monitoring the Path Forward

To ensure that the State of Basin Report becomes a dynamic management tool rather than a static assessment, a robust framework for monitoring progress is essential. This framework should track the basin's trajectory towards its sustainability goals and provide the evidence base for adaptive management. Future SoBRs should be produced on a regular cycle, for example, every five years, to create a consistent rhythm of assessment, planning, and course correction. This institutionalizes the SoBR as the primary mechanism for tracking basin-wide progress and holding all actors accountable.

Drawing on best practices from other transboundary basins like the Mekong and global standards such as SDG Indicator 6.5.2, a proposed indicator framework is presented below (McCracken & Meyer, 2018; Mekong River Commission, n.d.). This framework is designed to provide a holistic picture of basin health by tracking a balanced set of environmental, socio-economic, and governance indicators. By explicitly including governance effectiveness, the framework creates a powerful accountability mechanism, directly linking the health of the basin's ecosystems and communities to the performance of its management institutions.

Table 9-2. Proposed Indicator Framework for Monitoring Basin Health

Thematic Area	Key Indicator	Unit of Measurement	Data Source/Responsibility
1. Environmental Health	1.1 Lake Trophic State Index (TSI)	Index Value	Coordinated Lake Survey (LVBC, National Research Institutes)
	1.2 Mean concentration of key pollutants (Total N, Total P) at index sites	mg/L	Coordinated Lake Survey (LVBC, National Water Agencies)
	1.3 Percentage of basin area under forest cover	%	Remote Sensing/GIS (LVBC, National Forestry Authorities)
	1.4 Percentage of critical wetland area remaining	%	Remote Sensing/GIS (LVBC, National Environment Agencies)
	1.5 Biomass of key commercial fish stocks (Nile perch, Nile Tilapia Dagaa)	Tonnes	Stock Assessments (LVFO, National Fisheries Institutes)
2. Socio-Economic Well-being	2.1 Human Development Index (HDI) for basin districts/counties	Index Value	National Bureaus of Statistics
	2.2 Percentage of basin population with access to at least basic sanitation services	%	National Household Surveys (WHO/UNICEF JMP)

Thematic Area	Key Indicator	Unit of Measurement	Data Source/Responsibility
	2.3 Value of the fisheries sector (landed value and exports)	USD	LVFO, National Fisheries Authorities
	2.4 Prevalence of stunting in children under 5 in basin communities	%	National Health Surveys
	2.5 Number of people affected by climate-related disasters (floods, droughts)	Number	National Disaster Management Agencies
3. Governance Effectiveness	3.1 SDG Indicator 6.5.2: Proportion of transboundary basin area with an operational arrangement for water cooperation	%	National Reporting to UNEP/ UNECE
	3.2 Status of ratification of key EAC environmental protocols	Ratified / Not Ratified	EAC Secretariat
	3.3 LVBC Budget Sustainability Ratio	% of core budget from Partner State contributions vs. donors	LVBC Secretariat
	3.4 Number of active and financially sustainable co-management units (BMUs/WRUAs)	Number	Partner States (Ministries of Fisheries, Water)
	3.5 Public availability and accessibility of environmental data via LVB-WIS	Index (e.g., based on completeness and timeliness)	LVBC Secretariat

By acting decisively on the recommendations outlined in this report and rigorously monitoring progress through this framework, the Partner States of the East African Community can steer the Lake Victoria Basin away from the precipice of ecological decline and towards a future of resilience, sustainability, and shared prosperity.

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