Towards Climate Resilient Environmental and Natural Resources Management in the Lake Victoria Basin

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Abbreviations and Acronyms

BMU	Beach Management Unit
CR	Climate Resilience
DPSIR	Driver-Pressure-State-Impact-Response
DRM	Disaster Risk Management
EAC	East African Community
ENRM	Environmental and Natural Resources Management
EWS	Early Warning Systems
GFDRR	Global Facility for Disaster Reduction and Recovery
GRID	Global Resource Information Database
ICPAC	Intergovernmental Authority on Development (IGAD) Climate Predication and Applications Center
IPCC	Intergovernmental Panel on Climate Change
LAC	Local Adaptive Capacity
LVB	Lake Victoria Basin
LVBC	Lake Victoria Basin Commission
LVEMP	Lake Victoria Environmental Management Project
LVFO	Lake Victoria Fisheries Organization
NAC	National Adaptive Capacity
NPCT	National Project Coordination Team
PREPARED	Planning for Resilience in East Africa through Policy, Adaptation, Research and Economic Development
RABIT	Resilience Assessment Benchmarking and Impact Toolkit
RCMRD	Regional Centre for Mapping of Resources for Development
RCP	Representative Concentration Pathway
RECP	Resource Efficient and Cleaner Production
SLM	Sustainable Land Management
SLWM	Sustainable Land and Water Management
UNEP	United Nations Environment Program
USAID	United States Agency for International Development
WOCAT	World Overview of Conservation Approaches and Technologies

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Executive Summary

The Lake Victoria Basin (LVB) is a critical transboundary natural resource, underpinning the livelihoods and well-being of a dense and fast-growing population. The LVB has a total area of 194,200 km² and is shared by Burundi, Kenya, Rwanda, Tanzania, and Uganda. There are some 45 million people living in the basin, with around 80% of the population reliant on agricultural and livestock activities for their livelihoods; agriculture is largely rain-fed. More than 200,000 fishermen and their families depend on daily catches for their basic employment, and the fisheries industry is estimated to provide direct employment to more than 800,000 people. The fisheries are estimated to contribute between 2 and 3% to the GDPs of Kenya, Tanzania, and Uganda with Lake Victoria contributing the most to their freshwater fisheries. The Lake and its tributaries provide drinking water, waterway transport, and hydropower and have great potential for tourism.

The LVB has undergone intense environmental degradation for decades, resulting in significant ecological and economic problems. Rapid population growth, agricultural expansion, urbanization, and industrialization have mounted extreme pressure on the lake and its basin's ecosystems, and have led to the degradation of lands, and the loss of wetlands and forests in the basin. Terrestrial biodiversity is negatively affected by the loss of natural habitats. Insufficient monitoring and weak enforcement regulations on illegal- and over-fishing activities have reduced fish stocks, which threaten crucial livelihoods and food security. Water pollution from point-sources such as human settlements and industries and non-point sources such as agricultural lands and other land use forms in watersheds reduces water quality and causes eutrophication. In some sub-catchments, the nitrogen load can be as high as 1000 kg/km²/year due to unsustainable land use practices and soil erosion. As a result, water hyacinth, which is a notorious invasive species affecting fishing, water quality and waterway transport, and toxic algae, grows and spreads rapidly in many locations in Lake Victoria. Water resources management and abstractions from the Lake, including the discharge rate of its outlet at Jinja in Uganda, have the potential to affect water levels. These problems are strongly interlinked, with significant transboundary implications.

Climate change has been observed in the Basin. Across the basin, temperatures have consistently increased between 0.1°C and 2.5°C, based on data from 1920 to 2013, and some increases in annual rainfall totals have been identified. Per some projections, annual mean temperatures could increase by 0.5 to 3°C by 2050. Under the most pessimistic scenario, these increases could be some 3 to 5°C by 2090. Projections for rainfall are more uncertain and vary between seasons, with some models showing increased rainfall and others showing decreased rainfall totals.

The LVB and its inhabitants are vulnerable to the increasing effects of climate shocks, which would likely exacerbate its environmental problems. The LVB has a modified equatorial climate, which is largely warm and humid, with a bimodal rainfall pattern referred to as the “long rains” (March–May) and the “short rains” (October–December). Agricultural communities are highly reliant on these two rainfall periods. The basin has a history of being hit by floods and droughts, with short and long-term consequences for communities. A changing climate could be experienced through shifts in average conditions and patterns of extreme events. These changes could worsen environmental problems such as land degradation

and deteriorated water quality. Increased rainfall variability and changes to the timing of the rainy seasons could affect agricultural production and place more pressure on natural resources and drive further encroachment of wetlands and other environmentally sensitive areas through climate-change induced migration. More frequent episodes of extreme rainfall could increase erosion rates and damage sanitation infrastructure, leading to a decrease of water quality, fish stocks, and aquatic biodiversity.

The Lake Victoria Basin is a climate-change impacted hotspot in the making. A USAID-funded research project “The Planning for Resilience in East Africa through Policy, Adaptation, Research, and Economic Development” (PREPARED) showed that climate change could have negative impacts on water resources, agriculture, aquatic and terrestrial ecosystems, human health, energy production, and transportation. For example:

- Water levels in Lake Victoria are influenced by direct rainfall over the lake, runoff from the basin, evaporation from the Lake, and outflows into the Nile, the latter of which is controlled by two hydropower dams. While climate change could affect inflow and evaporation, the control of outflow is expected to be a significant factor. Changing lake levels could affect both water supply infrastructure and transportation.
- Fish stocks are threatened by climate change due to warmer waters and changing water quality.
- Increased rainfall could increase erosion and pollution, therefore impacting the lake’s water quality.
- Changing temperatures could introduce disease vectors into new areas and increase the risk of malaria and other vector-borne diseases.

As resources come under greater pressure outside the basin, research by the World Bank has shown that the LVB will be a hotspot for climate-induced migration, which could exacerbate conflicts over resources, and increase human exposure and vulnerability to climate hazards.

Improving Environmental and Natural Resources Management (ENRM) and enhancing climate resilience are regional and national development priorities that require government actions and investments. Regional organizations such as the East African Community (EAC) and regional institutions including the Lake Victoria Basin Commission (LVBC) and the Lake Victoria Fisheries Organization as well as the governments of the five LVB countries have established policies and strategies at the regional and national level to address ENRM and climate change. For example, the EAC has developed its Climate Change Policy, Strategy, and Master Plan and the LVBC developed a Lake Victoria Basin Climate Change Adaptation Strategy and Action Plan for 2018–2023. Each of the LVB countries have established institutional frameworks, policies and strategies to address environmental degradation and climate change. These include Kenya’s Climate Change National Adaptation Plan, Tanzania’s National Climate Change Strategy, and Uganda’s National Climate Change Policy. Some environmental and climate actions are mandated through national laws, such as Kenya’s Climate Change Act, which was passed in 2016. Some national and regional programs, in areas such as climate smart agriculture and water supply, have started to embed action to address Climate Change, although more efforts are necessary to better integrate climate resilient measures in ENRM.

A study funded by Global Facility for Disaster Reduction and Recovery (GFDRR) was carried out to assess and identify climate resilient ENRM interventions for future

investments. The study included the following four intertwined components: (i) a literature review of climate change activities and impacts; (ii) a climate risk assessment for the Lake Victoria Basin, based on a case study of three communities in the Mwanza Region of Tanzania; (iii) an institutional gap analysis and needs assessment for addressing climate change; and (iv) the assessment and identification of climate-resilient investments for the Lake Victoria Basin.

To deepen the understanding of the climate-induced risks posed in the basin, a community-level participatory study was undertaken in the Mwanza Region of Tanzania.

Three typical communities--representing rural villages, urban neighborhoods, and fishing communities, respectively--were selected in the Mwanza Region, Tanzania. Their exposure to climate hazards, their vulnerability, and the resulting risks were assessed through participatory exercises. The three communities were all exposed to varying degrees of flood hazards, which has brought the loss of livelihoods, damage to property, and health risks such as cholera outbreaks. Fishing communities were exposed to storms which have resulted in significant losses of life. Water scarcity was also a frequently identified hazard, which encouraged the encroachment into wetlands, and resulted in greater conflicts over water and land resources. Crops were often affected by pests, whose distribution was thought to be changing. These communities were vulnerable to climate shocks due to a lack of resources, inadequacies in the planning system, and in many cases a lack of knowledge and information on climate. The climate risks identified in these three communities are likely to be representative of similar risks, that could be repeated across the LVB.

An institutional gap analysis for addressing climate change and ENRM in the LVB has been conducted and identified institutional gaps at the regional and national levels. The analysis first reviewed the main governmental agencies and organizations, policies, strategies and plans that address climate change and ENRM. It then assessed gaps in the capacity of national institutions to adapt to climate change, considering key functions such as assessing risks, prioritizing actions, managing knowledge, coordinating activities and implementing activities. The results of the gap analysis were discussed and validated through stakeholder workshops. Key findings of the institutional gap analysis are as follows. First, climate considerations have not yet been mainstreamed in many investment programs and activities. Despite the existence of national strategies, policies and plans, coordination challenges remain at the regional level and among various government agencies within a country. The mainstreaming challenge is, in some cases, also linked to weaknesses in technical capacity and financial resources. Second, information that could be useful to guide ENRM and climate resilience is scarce. Access to this information and knowledge, along with its management and application, remain a challenge at all levels. Third, at the local or community levels, some of these aforementioned gaps are compounded (for example, lack of access to information). Access to resources can be challenging during disaster or climate shocks, and access may not be shared equitably. Women and other disadvantaged groups may face particular problems in this regard. In some cases, a lack of participatory planning was recognized.

The study further proposed and adopted a practical method to assess various ENRM investment options according to their contribution to enhancing climate resilience (CR).

The contribution was assessed through a qualitative approach which considers the contribution that investments make to strengthening five attributes of resilience -- Robustness, Learning, Inclusion, Flexibility, and Self-Organization. These attributes were selected based on the combined results of the climate risk assessment and the institutional gap analysis. For example,

the ‘Learning’ attribute was selected because of its key link with weaknesses in technical capacity and knowledge management. The assessment made use of a scoring system related to the number of attributes that could be strengthened by the investment. Furthermore, an assessment was also made of the contribution to climate adaptation and mitigation. These assessments were based on technical guidance available in the literature, such as guidance by the World Overview of Conservation Approaches and Technologies (WOCAT).

ENRM measures that would strengthen climate resilience were identified and grouped in the following areas.

- **Enhanced transboundary cooperation on environmental and natural resources management.** Investments should focus on i) Enhanced regional planning; ii) Improved enforcement and implementation of existing policies; iii) Improved knowledge management and monitoring; iv) Improved Early Warning Systems (EWS); and v) Institutional and capacity development.
- **Tackling non-point source pollution through Sustainable Land and Water Management (SLWM), and sustainable fisheries and lake management.** Investments should focus on i) Agronomic techniques such as conservation agriculture, and integrated soil fertility, ii) Agro-forestry, silvo-pastoralism, and community forest management in drylands iii) Integrated crop-livestock management and rangeland management; iv) Water management and rainwater harvesting; v) Climate-resilient fisheries management; and vi) Community level capacity and institutional strengthening. The role of engaging vulnerable groups and the focus on issues such as gender equity are particularly important in this investment area.
- **Tackling point source pollution through improved municipal wastewater and sanitation management and industrial pollution control.** Investments should focus on i) Investments in sanitation, stormwater and solid waste infrastructure; ii) Promoting resource efficient and cleaner production; iii) Improved monitoring and research on pollution; and iv) Capacity development and institutional strengthening of potentially polluting industries and the agencies that regulate them. CR principles should be incorporated into the design and construction of new infrastructure.

The Climate Resilience assessment methods could be further improved through the application of quantitative techniques. As an ENRM measure was assessed and scored by the number of climate resilience attributes to which the measures could contribute, this makes the proposed method qualitative. How to quantify the impacts of ENRM measures on reducing climate risks and building climate resilience can be further done in specific locations where a measure would be implemented and its impact on resilience can be modeled. Also, beyond using climate resilience as a criterion, technical, economic, financial, environmental, and social criteria, among others, are equally important and should be applied during project appraisal for final selection of investment activities. Finally, while this study has highlighted what measures should be undertaken to enhance climate resilience, it remains an open question as to how the institutions can be incentivized to undertake action. This is important but beyond the scope of this study. A deeper institutional and political analysis could pave the way to unlocking action on climate change in the Lake Victoria Basin.

1 Introduction

The Lake Victoria Basin (LVB) is a critical transboundary natural resource which extends over five countries Burundi, Kenya, Rwanda, Tanzania, and Uganda, of which Kenya, Tanzania, and Uganda directly border the lake (see Figure 1). The basin, with a total area of 194,200 km², is home to about 45 million people, and is one of the most densely populated regions in Africa. The population continues to increase rapidly and the trend is expected to continue for the foreseeable future. The basin also has high levels of poverty.

Source: Lake Victoria Basin Commission and GRID-Arendal, 2017)

Figure 1. Lake Victoria Basin Map

The LVB underpins the livelihoods and well-being of its growing population. Agriculture, livestock, and extensive fisheries activities provide incomes and create the foundations for food security. The LVB has undergone intense environmental degradation for decades due to rapid population growth, agricultural expansion, urbanization, and industrialization. The countries in the basin have to face significant environmental problems ranging from water pollution, lake eutrophication, the spread of invasive species, soil erosion and sediments, loss of wetlands and other habitats, fish stock depletion, and so on.

The basin and its inhabitants are vulnerable to the impacts of climate shocks, and the region has a history of floods and droughts with devastating consequences. The region is expected to become warmer as global temperatures continue to rise from increased atmospheric concentrations of greenhouse gases. It is anticipated that climate change will be experienced through changes to average conditions and extreme weather patterns, as well as greater variability. A changing climate is likely to exacerbate the challenges of environmental and natural resource management (ENRM).

To control environmental degradation and reduce climate change risks in the LVB, regional organizations such as the East African Community (EAC) and regional institutions like the Lake Victoria Basin Commission (LVBC), Lake Victoria Fisheries Organization (LVFO) and the governments of LVB countries have established a number of environmental and climate change policies and strategies. Regional cooperation on ENRM is clearly stated in the EAC Treaty and the founding protocol of the LVBC. The EAC has established its Climate Change Policy. Each of the five LVB countries have established institutional frameworks, policies and strategies to address climate change. These include Kenya's Climate Change National Adaptation Plan, Tanzania's National Climate Change Strategy, and Uganda's National Climate Change Policy. Some environmental and climate actions are mandated through laws, such as Kenya's Climate Change Act which was passed in 2016.

The World Bank Group also recognizes that building climate resilience is essential to the goals of ending extreme poverty and promoting shared prosperity (World Bank, 2013). The objective of the World Bank's 2019 Climate Change Action Plan is to increase the emphasis of its investments on adaptation and resilience. The World Bank's Plan aims to: (i) boost climate financing; (ii) drive a mainstreamed whole-of-government programmatic approach; and (iii) develop a rating system to track investments in adaptation and resilience (World Bank, 2019a). The World Bank has actively assisted the LVB countries in ENRM.

The LVB countries have taken action to address ENR degradation in the lake and its basin using the external technical and financial supports. A number of environmental management programs and projects have been instigated in the basin. A primary one is the Lake Victoria Environmental Management Program (LVEMP), which was implemented by EAC and its five member states in the LVB with financial support from the World Bank, GEF and other international organizations. LVEMP aimed to address environmental degradation issues, and climate resilience was not yet a focus of the project. Given the growing threat climate change poses to the basin, building climate resilience through investment activities is necessary for future investment programs in the basin.

Environmental management and climate actions are intertwined and should not be handled separately. There is an opportunity to address these two goals and implement win-win solutions through the identification and integration of climate-resilient ENRM investments. A study "Integrating Climate Resilience in Environmental and Natural Resources Management in the Lake Victoria Basin (LVB)" was undertaken in 2018-19, with the financial support of the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR). The study aimed to deepen the understanding of climate and extreme weather risks in the Lake Victoria Basin and identify, assess, and integrate climate resilience activities, both technical assistance and physical investments, into the future investment programs in ENRM. The study has four components: (i) a literature review of climate change activities; (ii) a climate risk assessment for the Lake Victoria Basin, based on a case study of three communities in the Mwanza Region of Tanzania; (iii) an institutional gap analysis and needs assessment for addressing climate change; and (iv) the assessment and identification of climate-resilient investments for the Lake Victoria Basin. Four technical reports were completed from each component of the study and listed in Appendix 1.

This report is a synthesis of the key findings and results of the four technical reports, with a focus on the assessment of Climate Resilience (CR) contributed by ENRM measures. This

report is structured as follows. After the introduction, Chapter 2 presents the terminology, a review of the approaches to building climate resilience, and an overview of the methodology used in this study. Chapter 3 first provides a literature review of climate change and ENRM in the LVB, including a review of environmental and climate challenges and ongoing initiatives. It also surveys the major climate hazards and risks in the basin through a study of historical events, projections of climate change, and potential impacts to different sectors across the basin. Chapter 4 presents an assessment of climate risks at the micro-scale, focusing on three community case studies in Tanzania's Mwanza Region—an assessment undertaken using participatory approaches. Chapter 5 examines the institutional frameworks for addressing environmental and natural resource management and climate change and describes the key gaps and needs. Chapter 6 identifies and assesses ENRM interventions that could strengthen climate resilience. Recommendations and suggestions for improvements are presented in Chapter 7.

2 Terminology and Methodology

While enhancing climate resilience through appropriate development strategies and investments has been highlighted in the LVB, one technical challenge that governments and international development institutions face is how to identify, assess and prioritize climate-resilient interventions for financing. This chapter presents the definition of climate adaptation, resilience, and mitigation and outlines the methodology used in the analysis.

2.1 Definitions of climate adaptation, resilience, and mitigation

The terms ‘climate resilience’ and ‘climate adaptation’ are often used interchangeably, or without distinguishing between the two. In this study we make a distinction between adaptation as a process, and resilience as a desired set of abilities.

Climate adaptation is defined as “the *process* of adjustment to actual or expected climate and its effects” (IPCC, 2014). This means taking action so that countries, cities, communities, businesses and individuals are less likely to be negatively affected by the risks posed by climate change. In the context of environmental management in the LVB, adaptation is focused on the process of ensuring that climate shocks do not negatively affect the status of the environment, including water and land quality. Adaptation places an emphasis on beneficial changes (Green Climate Fund, 2019). However, there is a risk that efforts to adapt can lock-in long-term negative effects through maladaptation. Examples include infrastructure such as coastal flood defenses that encourage development into vulnerable areas, or measures to protect sites from erosion that can negatively affect biodiversity and water quality (Magnan et al., 2016).

Resilience, used literally with very specific applications in physics and materials science, is defined as “the act of rebounding or springing back” (OED Online, 2019). Resilience is also defined figuratively as “the quality ... of being able to recover quickly or easily from, or resist being affected by, a misfortune, [or a] shock,” and its definition includes the notion of robustness and adaptability (ibid.). This second sense of resilience has given rise to its widespread use in the technical and scientific literature with a diversity of interpretations, which include engineering resilience, ecological resilience, social resilience, and social-ecological resilience.

Engineering resilience focuses on the resistance to disturbance and speed of return from a disturbance (Holling, 1996). In infrastructure management, one application of this approach is to consider the system’s performance using a metric such as the supply capacity, and to assess the time taken to recover to an acceptable performance level after a shock (Bruneau et al., 2003).

Ecological resilience arises from the recognition that an ecosystem can fluctuate greatly, but still be resilient. It is defined as “a measure of the ability of these [ecological] systems to absorb changes of state variables, driving variables, and parameters, and still persist.” (Holling, 1973). This approach recognizes the inherent dynamism of ecosystems, and the “domains of attraction” around which they fluctuate. It is possible to employ metric-based indicators that quantify changes to the system’s statistical properties, or parameters of computer models that seek to represent the system’s behavior (Scheffer et al., 2015).

Social resilience considers the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change (Adger, 2000). Social

resilience may be measured through indicators for factors such as trust, social capital, leadership, and resource dependency (Maguire and Hagan, 2007).

The last conceptualization is *social-ecological resilience* which recognizes the links between human society and the environment and is defined as “the capacity to adapt or transform in the face of change in social-ecological systems, particularly unexpected change, in ways that continue to support human well-being” (Folke et al., 2006). This approach is adopted in this study as the framework for climate resilience, which recognizes the Lake Victoria Basin as a social-ecological system, where climate is the principal, although not exclusive, source of shocks.

Adapted from the definition of IPCC (2014), **climate resilience** in this study is defined as: *the capacity of environmental systems (or the broader social-ecological systems) in the basin to cope with hazardous climate shocks, trends, or disturbances, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation*. This can be translated into three core capacities: absorptive, adaptive and transformative capacities. *Absorptive capacity* is the ability of people, assets, and systems to prepare for, mitigate, or prevent negative impacts of hazards so as to preserve and restore essential basic structures and functions. *Adaptive capacity* is the ability of people, assets, and systems to adjust, modify or change characteristics and actions to moderate potential future impacts from shocks so as to continue to function without major qualitative changes. *Transformative capacity* is the ability to create a fundamentally new system so as to avoid negative impacts from hazards (World Bank, 2017).

Lastly, **climate mitigation** refers to actions to reduce emissions of greenhouse gases and enhance sinks (IPCC, 2014). These actions reduce the concentration of greenhouse gases in the atmosphere and limit the rate or magnitude of climate change. Investments to reduce emissions may include adopting cleaner technologies and renewable energy and increasing energy efficiency. Investments to increase sinks may include reforestation, afforestation, and the protection of wetlands.

2.2 An overview of the process and methods for building and assessing climate resilience

The Driver-Pressure-State-Impact-Response (DPSIR) Framework (see the details in Box 1) has been applied to understand the conceptual relationships between various elements in a wide range of social, economic and ecological systems (Lewison et al, 2016). In particular, it can be a useful tool to help explain the relationships between the factors that lead to environmental degradation and negative impacts on society, how these factors are exacerbated by climate change, and how responses can mitigate these challenges.

DPSIR can be applied to the presentation of environmental degradation and climate change issues in the LVB. For example, population growth, a key driver in the basin, leads to pressure from the extensive use of land for agriculture. This has adversely affected the environmental state through pollution discharges, soil erosion and reduced water quality. The consequence is a set of impacts on the economy and society, such as reduced agricultural productivity. Possible responses include promoting Sustainable Land and Water Management (SLWM) practices to reduce these pressures and therefore reduce the state changes and negative impacts. Responses will affect the drivers, the pressures, the state and the impacts.

Box 1: Drivers-Pressure-State-Impact-Response Framework

DPSIR (drivers, pressures, state, impact and response) framework is a conceptual model for describing the interactions between society and the environment. According to Patrício et al. (2016), the five components of this conceptual model are as follows:

- Driving forces (*drivers*) are basic sectoral trends that can lead to pressures on the natural environment;
- *Pressures* are the human activities with the potential to affect the natural environment;
- *State* reflects the observable state of the natural environment;
- *Impacts* are the effects of changes in the natural environment that can have an impact on society;
- *Response* addresses the actions that society can take to change or mitigate against negative impacts and degradation of the environmental state.

Figure 2 illustrates how climate change is integrated into this framework by visualizing it as an external factor that adds to the pressures and adversely affects the environmental state, thus leading to impacts in human society. It is worth noting that DPSIR is a simplified conceptual framework and may fall short of capturing the interrelationships and interplay between climate change and various elements in social, economic and environmental systems in the real world.

Figure 2. DPSIR framework including climate change

The DPSIR framework is further used in Chapter 6 of the report to describe the linkages between proposed climate resilient interventions and their expected impacts on changes in environmental degradation and climate change adaptation. The process of addressing climate adaptation and building resilience has been well established in literature. For example, the US's Third National Climate Assessment (Bierbaum et al., 2014) adopted the following five steps:

Step 1	Identifying and understanding risks;
Step 2	Planning, assessing, and selecting options;
Step 3	Implementation;
Step 4	Monitoring and evaluation; and
Step 5	Revising Strategies/Processes and Information Sharing.

This study primarily covers the first two steps in the LVB. In Step 1, identifying the risks of and vulnerabilities to climate change can be undertaken through two broad approaches, which are described as ‘top-down’ or ‘bottom-up’ (Dessai and Hulme, 2004). Top-down approaches typically depend on computer models, including climate models, which drive impact models (e.g. of flood risk or food security) at the relevant local scales to assess impacts, risks and vulnerabilities. The bottom-up approach is based on surveys and other participatory approaches at the community scale that seek to identify the factors that affect vulnerability.

The planning, assessing, and selecting option in Step 2 should proceed after risk and vulnerability assessments, and encompass both the identification of options and their assessment. Identification and assessment require intensive analytical work and they are normally conducted separately, as was the case in this study.

The climate resilience contribution of an investment can be assessed and prioritized through *formal* (quantitative) or *informal* (qualitative) approaches (PROVIA, 2013). The formal (quantitative) approaches include Cost-Benefit Analysis, Cost-Effectiveness Analysis, Multi-Criteria Analyses, Robust-Decision Making, and so on. The first two have been frequently used for economic evaluation and decision making. Multi-Criteria Analysis is suited to multiple objectives, where impacts and benefits are quantifiable, but not necessarily in monetary terms (UNFCCC, 2016). The approach can also include assessments of factors such as equity, flexibility, political acceptability, and urgency (Champalle et al., 2015). Significant uncertainties exist in the climate adaptation process. The Robust-Decision Making approach is a way to explore uncertainties by examining multiple scenarios, which seeks to identify robust, rather than optimal decisions (Weaver et al., 2013).

Informal approaches include participatory and deliberative measures that elicit information from stakeholders to identify preferences, or intuitive approaches that rely on cognitive processes and expert experience and judgement to select appropriate investments.

Various measures have been proposed for building resilience (Biggs et al., 2012; Berbés-Blázquez, 2017; Sterk et al., 2017), for example:

- maintain diversity and the redundancy of species, landscape types, actors and institutions;
- manage connectivity of resources, species and people;
- manage slow variables and feedback;
- foster complex adaptive systems (CAS) while considering social-ecological interactions;
- encourage learning by acquiring new information, skills or understanding;
- broaden participation by actively engaging stakeholders in projects; and
- promote polycentric governance systems.

A main question that this study faced is how to assess the contribution of various measures for building resilience to climate change and identify and integrate them into development programs and projects. Heeks and Ospina (2016) proposed the Resilience Assessment Benchmarking and Impact Toolkit (RABIT) approach, which can be used to identify and assess climate-resilient interventions, as well as for benchmarking and monitoring purposes. RABIT posits that resilience is enabled by the primary attributes of *robustness*, *self-organization*, and *learning*, along with the secondary enablers of *redundancy*, *rapidity*, *scale (or connectedness)*,

diversity, flexibility, and equality (or inclusion). Table 1 presents these attributes along with examples of markers that serve to help identify them.

Table 1. Resilience attributes, definitions, and markers presented in RABIT approach.

Attribute	Definition	Markers
Robustness	System's ability to withstand the impacts of shocks and fluctuations and maintain its characteristics and performance.	a) Physical preparedness and protection b) Institutional capacity c) Multi-level governance and networking
Learning	System's ability to generate feedback used to gain or create knowledge and strengthen relevant skills and capacities.	a) Capacity building b) New and traditional knowledge c) Experimentation and discovery
Redundancy	Extent to which the system's resources and/or institutions are substitutable so that the system can withstand impacts and continue to operate in the event of a disruption or degradation.	a) Resource sparseness b) Functional overlaps and interdependency c) Resource substitutability
Rapidity	Speed at which assets can be accessed or mobilized by system stakeholders to achieve goals in an efficient manner.	a) Rapid resource access b) Rapid resource assessment/coordination. c) Rapid resource mobilization
Connectedness	Breadth of assets and structures a system can access, at multiple levels, in order to effectively bounce back from or adapt to the effects of disturbances.	a) Multi-level networks and cross-scale integration b) Resource access and partnerships c) Cross-level interactions
Diversity	System's ability to undertake different courses of action with the resources at its disposal, innovate and utilize the opportunities that may arise from change.	a) Multiple courses of action b) Emerging opportunities c) Innovation backbone
Flexibility	System's ability to respond to uncertainty associated with climate change and disaster risk.	a) Adaptable decision-making b) Diverse response mechanisms to risks and opportunities c) Component modularity and integrability
Inclusion	Extent to which the system provides its members with equal access to rights, resources and opportunities.	a) Strengthened competencies/ gap reduction b) Inclusiveness and participation c) Openness and accountability

Self-organization	Ability to independently re-arrange functions and processes in the face of external disturbances, diagnose problems, assess priorities, and/or mobilize resources to initiate solutions.	a) Collaboration/Consensus building and Participation b) Social networks c) Local leadership and trust, including psycho-social dimensions (e.g. belief, motivation, hope, perceived self-efficacy)
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Source: Heeks and Ospina (2016)

An extended version of the RABIT approach identified eleven attributes: preparedness, robustness, protection, recovery, rapidity, diversity, redundancy, flexibility, inclusion, integration/connectedness, and learning (World Bank, 2018). These attributes can contribute to building the three core resilience capacities described in the previous section: absorptive capacity, adaptive capacity, and transformative capacity. It is necessary to note that the relationships between these attributes and the building of the core capacities are not necessarily linear, and their strengthening may arise from the interaction and combinations of attributes. For example, adaptive capacity may arise from improved flexibility and learning.

Other authors have also proposed their own list of attributes for climate resilience. Most recently, Grafton et al. (2019) proposed a framework for quantifying resilience through context-specific metrics that reflect three characteristics: resistance, recovery, and robustness.

Models of varying levels of complexity can be used in the assessment process. Integrated assessment models have been advocated as tools for modelling interactions between sectors such as water, land-use, agriculture, and urban resilience (Andersson-Sköld et al., 2015; Harrison et al., 2016). Other approaches include participatory modelling frameworks (Inouye et al, 2017) and Agent-Based Models (Gotts et al., 2018).

Regarding the monitoring and evaluation of investments, techniques are needed to measure resilience before (benchmarking) and after interventions to assess their effectiveness. The most common approach for measuring resilience is by using indicators (Quinlan et al., 2016). Indicators can be based on quantifiable proxies, or qualitative or semi-quantitative scoring systems. These assessments may be driven through participatory or expert-led approaches, or by using models and collected data. However, Quinlan et al. (2016) argue that “*measuring and monitoring a narrow set of indicators or reducing resilience to a single unit of measurement may block the deeper understanding of system dynamics needed to apply resilience thinking and inform management actions.*” The World Bank has been advocating the use of quantifiable metrics that can be used to assess resilience-building investments (World Bank, 2018). Despite this, Hallegatte and Engle (2019) argue that, although many elements of resilience--such as governance, voice and empowerment--are difficult to quantify, they should not be ignored. Qualitative attributes can be partially measured with quantitative metrics. For example, learning may be measured by the number of staff that have completed a training course, although this may not be a perfect metric.

2.3 Methodology adopted in this study

A variety of research methods were adopted in this study. To assess climate risks and vulnerabilities, the study adopts a combination of top-down and bottom-up approaches. A literature review was conducted first, with the studies on climate impacts, risks and predications reviewed in Chapter 3. Then, a bottom-up assessment of climate risks and vulnerability at the

community level was carried out through the participatory case study of three communities in Tanzania’s Mwanza Region, presented in Chapter 4.

After the risk assessment, an institutional analysis was conducted to understand the development strategies and institutional arrangements and gaps at the regional and national levels to undertake core functions such as planning, assessing climate risks, managing knowledge, prioritizing options, and implementing climate risk management measures and identify the needs and actions necessary for climate resilience in the future.

The analysis also further identified investment activities for environmental and natural resource management in the LVB, and that activities should meet three criteria: (i) improve ENRM, (ii) contribute to addressing the identified risks and gaps, and (iii) align with existing regional and national development strategies.

For the assessment and prioritization of investment options that support the building of climate resilience, this study adopts a qualitative approach, built on the RABIT approach and its extended version (World Bank, 2018). To be more practical and easier to use, this study selects five attributes that enable resilience: Robustness, Learning, Inclusion, Flexibility, and Self-organization. A justification for selecting the five attributes relies on the analysis presented in Chapters 3, 4, and 5 and is presented in Table 2

Table 2. Resilience attributes selected for the Lake Victoria Basin

Attribute	Justification
Robustness	The ability to withstand climate shocks is a recurring theme in Chapters 3 and 4. For example, incomes and food sources can be vulnerable to hazards, or slopes and soils can be washed away during heavy rainfall.
Learning	Learning is related to information access and technical capacities. These were both highlighted as key gaps in Chapter 5.
Inclusion	The climate risk assessment carried out in Chapter 4 identified that some groups are more vulnerable to climate change and struggle to access resources. Furthermore, the lack of participatory planning was identified as a key institutional gap.
Flexibility	Flexibility is strongly linked to redundancy and diversity and relates to the ability to undertake different actions. This may be due to access to alternative resources and plans that react to changing situations. Chapter 4 identified alternative income streams as a way for communities to be resilient and avoid unsustainable practices.
Self-organization	This attribute is strongly related to a community or organization’s ability to plan, prioritize, and coordinate activities. Chapter 5 has identified the lack of coordination across hierarchies and sectors as an institutional gap.

The four attributes dropped from the RABIT list were Redundancy, Rapidity, Connectedness, and Diversity. In the case of Redundancy and Diversity, a conceptual overlap was identified with Flexibility. In the case of Rapidity, the analysis in Chapters 3, 4, and 5 did not identify the speed of accessing resources as critical, as many of the hazards are slow moving (e.g. water

scarcity). Where hazards do emerge rapidly, the concept of Robustness overlaps with Rapidity. Lastly, Connectedness was considered to overlap with Self-organization.

Each proposed investment option is assessed against its ability to directly contribute to these attributes. The scoring system is binary, and each attribute considered to be enhanced by a measure is assigned a tick (✓). The number of attributes linked to each measure is used to develop an overall score for its contribution to resilience. The scoring system is shown in Table 3. It should be noted that an investment option which strongly contributes to strengthening one attribute could be more favorable than ones that weakly contribute to multiple attributes. As an example, a flood defense wall that protects a water treatment facility might significantly increase the facility's robustness, however, it does not contribute to the attributes of learning, self-organization, or flexibility. Despite this, such flood infrastructure has a role to play in adaptation and should not be discounted. Therefore, the score may be biased in such a case. Nevertheless, the method adopted here remains a useful practice tool for governments to quickly understand and select climate resilient options.

Table 3. Scoring system for resilience assessment

Number of attributes	Contribution to resilience	Score
0	None	0
1-2	Limited	+
3	Moderate	++
4-5	Extensive	+++

The methodology for assessing the contribution to adaptation and mitigation depends on the types of investments. It is especially difficult for non-physical investments--mainly referring to transboundary cooperation, capacity building, and financing--because there can be no simple answer to the impact such measures will have on climate adaptation or mitigation. A scoring approach with a 4-point scale (0, +, ++, +++) is adopted for 'soft' investments. A score of zero means the investment contributes nothing to climate adaptation or mitigation. Measures with the potential to contribute indirectly to climate adaptation or mitigation only when combined with other investments are rated as +. An example of this group might be the development of a strategy that can only become effective with financing. The measures that directly contribute to adaptation or mitigation are given the score of ++. The measures that directly and strongly contribute to adaptation or mitigation are granted a score of +++. The measures that directly contribute to climate resilience generally receive attention and greater scores even though other underlining preparatory activities, such as data collection for climate resilience strategy development, are a necessary support and equally important. One should keep the limitation in mind in the proposed scoring system.

The assessment of the strengths of SLWM measures was based on best practice guidelines, developed for World Overview of Conservation Approaches and Technologies (WOCAT). and the Food and Agriculture Organization of the United Nations (Liniger et al., 2011). These guidelines provided expert information on factors ranging from their contribution to reducing land degradation, improved livelihoods, and cost-effectiveness. In this study, key information was extracted on their contribution to (i) combatting land-degradation; (ii) resilience to extreme

dry weather; (iii) increased rainfall variability; (iv) extreme rainfall and storms; (v) rising temperatures; (vi) adaptation and mitigation; (vii) disaster risk mitigation; and (viii) carbon sequestration. Table 4 is the scoring system which was adopted for this study after Liniger et al., (2011).

Table 4. Scoring system for contribution of SLWM measures to adaptation

+	Slightly positive
++	Positive
+++	Very positive
NA	Data not available

The maximum score for the contribution to specific cases of extreme weather was identified as the score for adaptation. The score for carbon sequestration was used as the score for climate mitigation. Where data were not available, a figure was selected using information from the scientific and technical literature. Information from the literature was also selected for investments in point source pollution reduction. The detailed tables taken from Liniger (2011) are presented in Appendix 2. Resilience pathways, which visually demonstrate how the climate resilient investments can strengthen the attributes of resilience and enhance the three core capacities in LVB, are further presented at the end of Chapter 6.

3 Literature Review of Climate and Disaster Risks in the Lake Victoria Basin

This chapter reviews the environmental and climate challenges, climate change risks and impacts faced in the LVB. It is based on a literature review of available reports and materials. It presents information on the climate situation, identified trends, and projections and also provides a review of the current and potential impacts of climate change across sectors that include water resources, agriculture, and ecosystems.

3.1 Development and environmental and climate challenges.

The Lake Victoria Basin is one of the most populated regions in Africa with a density over 200 persons per square kilometer. Its population is continuously rising and the majority of people still live in poverty. The predominant population in the basin, estimated at 60% in 2007, is rural (Lake Victoria Lake Commission and GRID-Arendal, 2017), although significant urban centers exist such as in Kisumu in Kenya, Mwanza in Tanzania, Kigali in Rwanda, and Kampala in Uganda.

The livelihoods and well-being of communities in the basin strongly depend on the lake, aquatic- and territorial ecosystems, and other natural resources. Agriculture and livestock are the most important sectors for the livelihoods of the majority of the population and rain-fed agriculture systems are dominant (Lake Victoria Lake Commission and GRID-Arendal, 2017). More than 200,000 fishermen and their families depend on daily fish catches for their basic sustenance, and it is estimated that the wider fishing industry offers direct employment for more than 800,000 people (LVFO, 2016). The income from fisheries is estimated to indirectly support the livelihoods of over 3 million people (LVFO, 2016). The fisheries are estimated to contribute between 2-3% to the GDPs of Kenya, Tanzania, and Uganda where Lake Victoria contributes most to freshwater fisheries. The Lake and its tributaries provide drinking water, waterway transport, and hydropower and have significant potential for tourism.

The growing population and economic growth put greater demands on natural resources such as water, wetlands, forests, pastoral lands, and fish resources. These growing demands have not been appropriately managed and the LVB has undergone intense environmental degradation for decades, which results in significant ecological and economic problems. In addition to rapid population growth, agricultural expansion, urbanization, and industrialization have all mounted extreme pressure on the lake and ecosystems in the LVB and have led to the degradation of lands and the loss of wetlands and forests. Terrestrial biodiversity is negatively affected by the loss of natural habitats. Insufficient monitoring and weak enforcement of regulations on illegal- and over-fishing activities have reduced fish stocks, which threaten crucial livelihoods and food security. Water pollution from point-sources such as human settlements and industries and non-point sources such as agricultural lands and other land use forms in watersheds reduces water quality and causes eutrophication. In some sub-catchments, the nitrogen load can be as high as 1000 kg/km²/year due to unsustainable land use practices and soil erosion. As a result, water hyacinth, which is a notorious invasive species affecting fishing, water quality and waterway transport, and toxic algae grows and spreads rapidly in many locations throughout Lake Victoria. Water resources management and abstractions from the Lake, including the discharge rate of its outlet at Jinja in Uganda, have the potential to affect water levels. These problems are strongly interlinked, with significant transboundary implications.

The LVB is a climate-change impacted hotspot in the making. Communities in the LVB are recognized as vulnerable to climate change, which creates stressors that affect livelihoods and well-being (Gabrielsson et al., 2012). Climate change has and will continue to exacerbate the aforementioned environmental challenges. Increased rainfall variability and changes to the timing of the rainy seasons can critically affect agricultural production and food security. This in turn can place more pressure on natural resources and drive further encroachment of wetlands and environmentally sensitive areas. A 2018 World Bank demonstrated that the region is expected to become a hotspot for climate-induced inward migration (Kumari Rigaud, et al., 2018). This inward migration, driven by factors such as climate shocks and reduced agricultural productivity outside the basin, will add to the basin's already burgeoning population. There is a risk that more people will be drawn to unsustainable practices. The region is already exposed to natural hazards such as floods and landslides. If, as some climate projections show, intense rainfall becomes more frequent and extreme, the negative impacts on communities—such as the destruction of houses, infrastructure, and agriculture—will worsen. Heavier rainfall could increase erosion rates and causes damage to sanitation infrastructure, leading to diminished water quality.

3.2 Climate observations

The Lake Victoria Basin has a modified equatorial climate, which is largely warm and humid, with a bimodal rainfall pattern. Average daily minimum temperatures range between around 16-18 °C in the Lakeshore region and average daily maximum temperatures are generally between 25-30 °C (USAID 2017: Chap. 1), although some areas see average maximum temperatures greater than 30°C, and there are notably cooler areas in the Western Highlands of Kenya and elevated areas of Rwanda and Burundi. All the countries in the Lake Basin have witnessed increased average temperatures. Temperatures increased between 0.1°C and 2.5°C for both the maximum and minimum components, based on data from 1920 to 2013 (USAID 2017: Chap. 1).

The region has two major rainfall seasons, locally referred to as the “long rains” (March–May) and the “short rains” (October–December). Average rainfall across the basin varies from a low of 600 mm in Northern Tanzania to over 1500 mm in Eastern Kenya. The shorter rain season of October to December accounts for around 20% of the annual rainfall (USAID, 2017: Chap. 1). Rainfall is significantly higher over the Lake itself as a result of lake-breeze effects and can be over 3000mm on the lake's Nabuyonge Island. Annual rainfall totals are variable (USAID, 2017: Chap. 1). The Coefficient of Variation for annual rainfall, defined as the standard deviation divided by the mean, can be up to 30% in parts of Northern Tanzania and elsewhere. In terms of the rainfall trends, Awange et al. (2013) showed moderate increases in the annual rainfall across the Basin which seems to show a generally increasing trend in rainfall, although there is a large variability in monthly totals.

3.3 Climate projections

Climate projections are based on the outputs of climate models (General Circulation Models and Regional Climate Models). These are driven by emission scenarios and changes to the atmospheric concentration of greenhouse gases. Emission scenarios depend on narratives of global social-economic changes. These narratives are translated into Relative Concentration Pathways (RCPs), which describe changes to radiative forcing since pre-industrial times, measured in Watts per square meter (W/m²). For example, RCP4.5 assumes an increase in

radiative forcing of 4.5 W/m² by 2100. However, modelling the East African climate is challenging due to the influence of the African Great Lakes (Thiery et al., 2015).

Climate models consistently show that mean temperatures across East Africa and the Lake Victoria Basin are expected to increase, although there is less certainty about the magnitude. The IPCC (2013) projects that by 2050, annual mean temperatures could increase by 0.5 to 3°C. Under the most pessimistic scenario (RCP8.5), these increases could be around 3 to 5°C by 2090. Daily mean maximum temperatures from the 2050s, and for the range of seasons are presented in Figure 3.

Rainfall projections are more uncertain. The IPCC's 5th Assessment report shows that for East Africa, some of the models show increasing rainfall and others show decreases in rainfall overall (IPCC, 2013). USAID (2017: Chap. 7) used one model with mixed results. This model shows that overall, annually, precipitation totals are expected to increase, although this varies by season. The results show increased rainfall for all emissions scenarios over the October to December period. Across the March to May period, there seems to be a divide, where regions to the south and east are expected to become wetter, whereas to the north, they could become drier. Rainfall over the lake itself is expected to decrease, which could have implications for water levels.

Source: USAID, 2017

Notes: Each row corresponds to emission scenarios.

MAM – March April May; JJAS – June July August September; OND- October November December

Figure 3. Projected maximum temperature changes over East Africa by the 2050s in annual, MAM, JJAS, and OND periods

Source: USAID, 2017

Figure 4. Projected rainfall changes over East Africa by the 2050s in annual and seasons for Representative Concentration Pathway (RCPs)

In relation to extreme rainfall, the IPCC's 5th Assessment wrote that “over wet tropical regions, extreme precipitation events will very likely be more intense and more frequent in a warmer world.” Extreme rainfall is also expected to increase in the Basin (Akurut et al., 2014; Thiery et al., 2016; Ongoma et al., 2018). In relation to drought, current understanding of the impacts of climate change are highly uncertain (Yang and Huntingford, 2018). However, climate projections should be handled with care, when applied to decision making (Nissan et al., 2019).

3.4 History of climate hazards

Climate variability is associated with a history of extreme climate events in the basin. The LVB is prone to heavy rainfall, and there is a long history of flooding events across the basin. Some notable flood events occurred in recent years including in Nyanza Province (Kenya), when at least 24 people were killed in April 2012, and 98,000 displaced. In Kampala (Uganda) and the surrounding Wakiso district, floods in November 2007 left four dead and displaced 3000 people. Mwanza City in Tanzania is a flooding hotspot, where in 2015, heavy rain and flooding led to the airport's temporary closure.

As much of the Lake Victoria Basin's population is dependent on rainfed agriculture for food production, people are vulnerable to drought. There is a relationship between climate variability, agricultural productivity, and ultimately food security (USAID, 2017). Awange et al. (2016) reported that the Lake Victoria Basin has experienced six major drought periods between 1979 and 2014. Masih et al. (2014) reported on droughts that had affected Burundi, Kenya, Rwanda, Tanzania, and Uganda, demonstrating that droughts are a recurrent

phenomenon across East Africa, affecting large populations and causing significant economic damage. Other risks, that may or may not be attributable to climate change but could be exacerbated by climate change in time, include storms and lightning. A widely cited figure is that between 3,000 and 5,000 fishermen die on the Lake annually (International Federation of Red Cross and Red Crescent Societies, 2014). Lightning strikes are also a risk; Mary and Gomes (2015) identified 40 fatalities linked to lightning strikes that had occurred in the Ugandan part of the Lakeshore.

3.5 Climate Risks and Impacts

Lake levels have been observed to fluctuate significantly. Tong et al. (2016) concluded that Lake surface area, height, and volume has experienced significant fluctuations. This includes a rise of several meters in the early 1960s, which caused flooding, a sharp drop from 2000 to 2006, and the gradual increase period from 2007 to 2012. Water balance is a function of the runoff into the river, direct rainfall on the lake, lake outflows (at Jinja), evaporation, and water abstraction (Yin and Nicholson, 1998). Awange et al. (2008) found that climate patterns play a significant role in the pattern of long-term fluctuations. These fluctuations in water levels on Lake Victoria are known to have impacts on fisheries, transportation, livelihoods and water supplies.

- During high water levels, there is a risk of flooding to port infrastructure and access roads.
- Low lake levels could cause increased eutrophication and water hyacinth invasion.
- If levels are too low to allow vessels to enter ports, there could be increased transport costs.
- Low water levels could affect infrastructure such as water abstraction and ports.

The UNEP's Global Risk Platform shows that the flood risk across the basin is extensive. Warmer temperatures could accelerate the hydrological cycle, affecting precipitation and runoff, which could increase the frequency and intensity of floods and droughts (USAID, 2017). This concurs with climate projections that suggest increased likelihoods of intense rainfall in the future. Water resources could be affected by climate change, through changes in runoff and groundwater recharge and through changes in demand. Climate change could affect water quality in rivers and lakes. Surface water quality is particularly vulnerable due to potential concentration changes and increased soil erosion.

Many in the basin rely on rainfed agriculture, in terms of food security and income. Rainfall variability is one of the most significant factors affecting agricultural productivity. Unreliable rains could lead to enhanced periods of drought risk. Temperature increases could affect livestock, affecting both the pasture livestock rely on and their physiology, especially beyond 30°C.

Aquatic and terrestrial biodiversity could be affected by climate change through a number of pathways, including temperature, precipitation, salinity, river flow, nutrient concentrations, lake levels and storms (USAID 2017: Chap. 11). In 1984, a heavy rainfall event killed 400,000 fish, after sediments were mixed with nutrient rich mud (Ochumba, 1990). Over 200 species of fish in the lake and the basin are vulnerable to climate change changes (Sayer et al., 2018). Algae growth may be promoted through raised temperatures. Higher temperatures could affect fish physiology and promote the growth of fish parasites (Macnab and Barber, 2012). Increased

rainfall variability would affect vegetation growth and consequently affects pasture for livestock and habitats for wild animals. Increased warming could cause shifts in ecosystems, affecting composition and range of species.

Climate has the potential to affect human health through impacts on clean air, water quality, water availability, food, and shelter. Climate has the potential to affect disease vectors, such as malaria, extending their range and increasing risks (USAID, 2017: Chap. 11). Drought and floods are known to be linked with waterborne diseases such as cholera, and other diseases such as pneumonia (Olago et al., 2007). Changes to their frequency and intensity could therefore increase the likelihood of disease outbreaks.

Hydropower in the basin is sensitive to river flows (volume and timing), and in the case of the Nalubaale Power Station in Uganda, on the levels of the Lake. Increased runoff could increase the erosion and siltation of dams, affecting maintenance costs.

Even if there are no changes in the hazards themselves, exposure to disasters and climate risks are likely to increase as the region's population increases. This population increase, which derives from a range of socio-economic pressures, is being compounded by climate change and variability. Climate change can affect agricultural productivity and rural wages, and the availability of water resources, providing push factors that contribute to the decision to move, but these factors must be considered in conjunction with others such as government policies, and changes in economic structure that may favor urbanization. A recent study by the World Bank has estimated that the whole Lake Victoria basin will be an area of climate in-migration (Kumari Rigaud et al. 2018). Poverty, which remains persistent across the region, further compounds the impacts of climate change on communities in the basin.

In summary, the review demonstrates that there are significant climate impacts upon the basin. A number of climate hazards, which include flooding, droughts, and storms have had negative consequences for those living in the basin. These hazards have had secondary impacts such as the outbreak of diseases like cholera and impacts on fishing activities. The review has demonstrated that changes have been observed in the climate, including increases in temperature, and changes to rainfall patterns. Although projections are uncertain, studies show that these ongoing changes are likely to result in increased temperatures and more frequent intense rainfall. Increased rainfall variability may have consequences for water security. These climate risks are linked to the social-economic situation within the basin. The population, already growing rapidly, could be exacerbated by inward climate-induced migration from outside the basin. Poverty remains a persistent problem, which contributes to the vulnerability of communities. The review has demonstrated that climate change has the potential to negatively affect ENRM, with impacts on water resources, agriculture, and aquatic and terrestrial ecosystems, and that the intersection between climate change and ENRM needs to be addressed in tandem.

4 Community Case Study of Climate and Disaster Risk Assessment

The last chapter describes how climate change is likely to have wide-ranging and multi-sectoral effects across the LVB. However, the effects of climate change are mostly experienced by communities and individuals at the local level. Therefore, this chapter presents a bottom-up participatory analysis of climate risks faced by three representative communities in Mwanza Region, Tanzania.

4.1 The Mwanza Region and overview of its communities

Located on the south side of Lake Victoria, the Mwanza Region is one of 31 administrative regions in Tanzania and comprised of seven districts (Ilemela, Kwimba, Magu, Misungwi, Nyamagana, Sengerema, and Ukerewe). In the 2012 national census, its population was recorded as 2,772,500, and it was projected to reach 3.22 million by 2017 (Government of Tanzania, 2016). The climate in Mwanza is typical for the lakeshore region. Climate data for Mwanza City shows that average monthly temperatures range from 21.5 °C in July to 23.3 °C in October. It has a regional bimodal rainfall pattern with the ‘long’ rains peaking in April, and the ‘short’ rainy season peaking in November. Average annual rainfall is recorded as 1054 mm.

Mwanza City is the region’s capital and shared between the two municipal provinces of Ilemela and Nyamagana. It is the second largest city in Tanzania, and its population was measured in the 2012 census at over 706,000. The city, with a landscape scattered with boulders and outcrops, has grown around its port to become a hub for economic activity and tourism. Many of Mwanza’s hills have become covered by unplanned settlements. In addition to Mwanza City, the Region consists of a number of small towns and villages. Agriculture is the region’s major economic activity and source of employment. In urban areas, professionals, technicians, street vendors, and service workers make up a large part of the employment force.

To carry out climate risk assessments at the local level, the following three communities were selected from Mwanza Region and shown in Figure 5. They are: i) Bubinza, a rural village in Magu District; ii) Kayenze, a fishing community in Ilemela District; and iii) Mabatini, an urban community in Nyamagana District, Mwanza City.

Figure 5. Locations of three communities in the Mwanza Region

The communities were identified and selected based on the recommendation of Tanzania's National Project Coordination Team (NPCT) of LVEMP because of their previous engagement with the project, exposure to a range of climate and disaster risks, their profiles that are somewhat representative of typical communities in the Mwanza region.

Bubinza is a village with a population of around 6,000 people in 900 households. The majority grows crops for income and food. Smaller numbers grow crops and keep livestock, and a minority keep livestock only. A small number of people are involved in fishing and retail activities. Resource-related conflicts between farmers and pastoralists are common, over conservation of a forest reserve and over water resources. The village lies close to the Simiyu river which has a large basin of over 10,800 km². The river flows from the Ngorongoro Highlands through the Serengeti and into Lake Victoria, through an area of wetlands. The area is bisected by the Sirari-Mbeya road which runs from Mwanza to Nyahanga. This road crosses the wetlands and rivers at a number of bridges.

Kayenze lies along the lake shore. The village has a population of 1,349 people, of which 60 percent are involved in the fishing industry. The remainder of the community is involved in agriculture and business, and fishermen are organized into a Beach Management Unit (BMU). The BMU is responsible for organizing and managing the fishing community, including income and expenditure as well as fishing permits.

Mabitini is a densely populated urban community in Mwanza City. Its ward has an average density of over 11,000 people / km², and the community is bisected by the Mirongo River. The river is known as a source of flooding and its water quality is poor due to human and industrial waste. The river is also bisected by the B6 / Nyanguge Road. This thoroughfare is an area of high business activity, with workshops, shops and other industries. The community is characterized by poorly constructed and unplanned housing, with limited access to power and water. However, around 20 – 25% of the community is more affluent, with improved construction, utility supplies, and access to private transport.

Photo 1. Bubinza, a rural community

Photo 2. Kayenze, a fishing community

Photo 3. Mabitini, an urban rural community

4.2 Survey and participatory methods

The assessment of climate risks in the communities was conducted using a participatory risk assessment approach, utilizing techniques adopted from various guidance documents (Abarquez and Murshed, 2004; Dazé et al., 2009; Oxfam, 2012). In each community, a representative group of community members were selected, with the aid of the NPCT and community leaders. The activities included developing a **Historical Timeline** of events and developments, a **Seasonal Calendar** to describe the typical annual cycle of activities and climate, a **Hazard Map** of assets and resources exposed to hazards, a **Venn Diagram** depicting institutional relationships and support mechanisms, and a **Vulnerability Matrix** of key hazardous events. These were combined with a **Transect Walk** through each community.

4.3 Climate risks in the three communities

Bubinza

The rural village in Bubinza is exposed to two significant hazards, flood risk from the Simiyu River and water scarcity. According to locals, flooding formed the Duma in 1999. Flooding of the wetlands is thought to occur almost annually, lasting a few days. When floods quickly rise and recede, crops can withstand being submerged. However, when floods persist for days or weeks, the crops are destroyed. During the field visit, the Simiyu and Duma Rivers were flooded. The team witnessed submerged fields and several houses that had collapsed. Multiple structures, including commercial and residential buildings appeared vulnerable to hazards. Some of the most exposed houses were on legally allotted land. In addition to houses and crops, livestock are also threatened by floodwaters. One affected family, whose house had collapsed, was interviewed (Photo 4). They described how their house had collapsed during earlier floods, and how it may take several years for them to recover financially. Anecdotal evidence suggests that severe flooding has occurred around every ten to twenty years. In some periods, cholera was associated with flooding and heavy rainfall.

Dry periods have occurred regularly in the region. A traditional watering hole in the village is considered the only reliable water source during the dry season, although even this well has been known to dry up. The villagers reported water scarcity as their highest concern, and the community has also experienced rising temperatures. Increasing temperature affects the agricultural calendar, forcing villagers to delay planting and change the crops they plant. During periods of drought, households look to the rivers or Lake Victoria for water. Villagers, mostly women, must sacrifice time to collect water, which impacts other activities. For example, farmers forego preparatory activities before planting crops. Subsequently, fields are smaller in size and crop performance falls, creating food shortages for many households. The final hazard with possible links to climate is pest infestation. The pests are thought to increase in numbers with warmer temperatures. The most serious is the Army Worm, *Spodoptera frugiperda*, which attacks maize.

Social harmony seems to be a casualty of climate hazards in Bubinza. One example is when livestock keepers move closer towards the village and graze on cropland, changing livestock routes (Ernest et al., 2017). The team witnessed a bloody clash caused by a livestock keeper moving his livestock from a flooded area to graze on farmland. Although Magu District is supposed to have a mechanism to settle such conflicts, the community raised doubts about its

utility and reliability, and instead relies on informal mechanisms. These types of conflicts have been reported in the literature (Mwamfupe, 2015).

Photo 4. Damaged housing in Bubinza

Photo 5. Flooded farmland in Bubinza

One further exacerbating factor may be the diminishing Sayaka Forest Reserve. The Forest Reserve used to be closed canopy but is now deforested to the point of being open canopy. Encroachment came from the village, which expanded into the natural forest to plant maize, chickpeas, and vegetables, and which chopped down trees for household energy needs. The lack of a sustainable management plan for the area means that trees have not been replanted and the area remains mostly denuded.

One coping mechanism is to vary the types of crops that are planted or to adopt alternative livelihoods such as horticulture. Sorghum is more drought tolerant than maize and recommended for planting in dry areas. Another coping mechanism is to adapt to changing environmental conditions, for example through moving closer to the Duma River to obtain water. Community members are also flexible. When the Duma and Simiyu Rivers rise, more of Bubinza's residents take to fishing. The main differentiator in long-term vulnerability is an individual household's ability to recover financially. Villagers who maintained less diversity in their income sources were more susceptible to the financial effects of poor crop yields. Some households also have secondary plots of land. On the other hand, some families do not have this backup plan and have no other recourse but to turn to family and friends for help. Institutional support comes from a variety of sources, such as informal networks, religious organizations, schools, and external institutions such as the local government, including the police. Financial institutions were seen to have a small role in supporting the community.

Kayenze

Kayenze, a fishing community, is prone to a combination of climate change risks. The first of these relates to flood risk which affects parts of the village with poor drainage. Another hazard is from storms and high winds. This hazard affects houses on land and threatens the lives of fishermen out on the lake. The community stated that in 2018 heavy winds damaged seven houses. Fishing activities on the Lake are known to be dangerous, and the community recounted how in 2000, ten people died on the Lake. Fishermen reported that their primary method for determining the possibility for storms and rain is to use traditional techniques, instead of relying on national meteorological services. Fishermen see the storms as an opportunity to increase catches, as storms stir up the water and fish. The fishing industry is also affected by changes in the Lake level, as is the landing site. A refurbished fish landing site, paid for under a World Bank project, was found with its dock sunk into the water. The problem was reported to arise from poor design in neglecting the effects of lake variations and from poor maintenance. Drought and water scarcity are additional hazards. In 2017, the village, like much of the region, was affected by low rainfall totals.

In 2016, a cholera outbreak hit the village, particularly near the center and the fishing area, and around 20 people died. Outbreaks of cholera have been linked to floods and droughts. Along the shore, many people work with limited sanitation facilities, and practice open defecation.

Indirectly, an array of complex factors, including unpredictable weather patterns and increasing population density, are pushing people to migrate out of rural areas and into urbanizing ones like Kayenze. Many of the migrants are not only looking for economic opportunity in Kayenze, but to escape poverty traps aggravated by unreliable agricultural work in their home communities. One couple engages in fish drying because barriers to entry are low and the potential for profit is good. Kayenze has a significant HIV/AIDS crisis, which was identified as its third greatest hazard.

A lack of improved technology heightens vulnerability on the Lake for participants in Kayenze's fishing value chain. Many fishermen use canoes that are not sturdy enough to endure rough waters. Fishermen report that some canoes are fitted with outboard engines, which allows them to reach shore quickly and avoid personal disaster when a storm turns deadly. Although many canoes have engines, most in Kayenze do not. Most fishermen do not have mobile telephone reception on the lake, which isolates them before and during disasters.

Public policy has the potential to mitigate greater vulnerability to weather hazards. In contrast, the lack of regulatory enforcement has enabled greater vulnerability to climate change. Since the 1990s, Kayenze has seen an increase in farms along the lakeshore, including in the wetlands. The Government of Tanzania has actively emphasized economic growth through agriculture, with the unintended consequence of encouraging the use of even marginal lands for farming. When farmers cultivate wetlands, they disrupt critical aquatic habitats that often serve as fish breeding grounds— playing a part in disrupting the fish stocks upon which Kayenze’s fishermen and others around the lake rely. In addition, some of the pest species affecting crop production in the Basin, notably the ravenous fall armyworm, may credit their exponential growth in part to climate change.

Residents demonstrated considerable adaptability to changing conditions. For many the sheer fact of moving to Kayenze, and seeking new opportunities, is demonstrative of the ability to adapt to changing climate patterns. The team also observed the employment of simple mitigation measures to reduce risks to homes.

Another demonstration of reducing vulnerability is an increased awareness of the importance of the Lake as a shared resource and the need for all stakeholders to take care of it. Multiple community members explained that the use of smaller nets has negatively affected the catch of Daga fish. Realizing the link, fishermen adapted to using larger nets, and the stocks recovered.

From the institutional vantage point, community members rely on several governmental and non-governmental organizations for support. The community highlighted the role of informal networks as the most fundamental. Outside of kinship and friendship networks, religious institutions were considered the most reliable. Diverging views on the role of government were identified, and health services were considered limited. Finally, the Beach Management Unit was seen as serving a function in organizing economic activities in the beach area, but not necessarily dealing with natural hazards.

Mabitini

In the urban community Mabatini, flooding presents the greatest climate threat to lives, livelihoods, and economic assets. The community reported floods as far back as 1969 and 1971, and in 2000, 2008/2009, 2013, 2015/2016, and 2018. Flooding is most often associated with the heavy rains that fall between March and April/May, and from October to December. People in the neighborhood believe that the intensity of these climatic events has been increasing over time. Floodwaters can overtop the Nyerere Road, the community’s main thoroughfare. Community members reported that this hazard had become more pronounced through urbanization and land-use changes, with flash flooding occurring during the peak rains. Runoff collects in the eroded gullies that run down from the hilltops pushing high volumes of water very quickly towards the Mirongo River. One gully that the community specifically singled out has widened in recent years because of worsening erosion, a condition attributed to land use changes uphill.

The team triangulated the community’s assessment of the flood hazard through the literature review. Hambati and Yengoh (2018) showed that 38 percent of the area of Mwanza City is at a minimum exposed to flood hazards. The same study showed that 54 percent of Mbugani ward is exposed to flooding. Risk to life is significant. The community reported that several houses were destroyed, and 4 people lost their lives in 2000 alone. The community explained that five

homeless boys drowned in March 2018 floods, when they were caught under a bridge. Dwelling in these areas feeds into a continuous cycle of poverty whereby families live in potential disaster zones, and then inevitably suffer significant losses to their asset base.

The community market (shown in Photo 6) is directly adjacent to the river, with stall holders often required to remove their goods with little or no warning. The waters can rise extremely rapidly, reaching a significant height: in 2016 the floods reached a depth of 1.5m. Other key economic assets exposed to floods include garages and shops, which form a long informal commercial district. Not only can the flooding cause economic damage, it can also discharge pollutants into the river and lake.

Threats to economic assets pose problems for shared prosperity in Mwanza. Shops built within the buffer zone are, by definition, illegal structures. When poorer merchants are more exposed to economic losses than their richer compatriots, lacking the protection of social safety nets such as business insurance programs makes it difficult to increase wealth and economic resources. Heightened rainfall contributed to disease outbreaks, which include malaria and cholera.

The second hazard that community members reported was landslides and rockfalls. In 2016, a house was destroyed, and four people were killed as a result of falling boulders. These landslide areas were reported upslope from the Mirongo River on the river's south side. Landslides and rockfalls however, are much less common than flooding. The literature review highlighted a final risk: water scarcity. In 2006, the lake's water level, which is the main source of water in Mwanza, dropped below the intake level. As a result, additional pumps had to be installed to ensure municipal water supplies.

Photo 6. Market area adjacent to the Mirongo River

Several factors increase the community's vulnerability to climate-related hazards. Individuals have constructed houses and established small businesses within the river's buffer zone. Governmental regulations restrict construction on hazardous lands, defined in ways that include "land within sixty meters of a river bank, shoreline of an inland lake, beach or coast." But these regulations are not always followed. Before urbanization in the late 60s and early 70s, the area was largely wetlands and rice paddies. The waterlogging of the footpath running parallel to the

river is a seasonal reminder of this previous land use, as is the observation that certain parts of the neighborhood have dropped in elevation because of erosion. There are upstream concerns as well. Higher in the hills above Mabatini is a new neighborhood, Bugarika, a squatter community. Accelerated erosion in the gullies around Mabatini corresponds to the increasing amounts of human effluent and upslope rain runoff.

Vulnerability is increased because of poor transport infrastructure and maintenance along the river. Community leaders report that unsatisfactory installation and the strength of flood currents have washed away the safety guardrails on many of these pedestrian bridges. Solid waste pollution raises the risk of flooding through the clogging of channels and pipes, which have little maintenance. Lastly, limited access to weather-related information impedes the citizens' ability to make informed decisions. The inability of the Meteorological Service's to get information directly to affected populations means that flooding is not accompanied by early warnings.

The community highlighted religious organizations and the dispensary as being especially reliable in times of crisis. Informal networks, such as friends and family, were also significant. Some community members will take it upon themselves to clean up the river, removing obstructions from the water course, and working to stabilize river banks. Community members reported that they perceived the central government did not play a significant role in protecting their well-being during and after disaster risks.

4.4 Summary of climate risks in the Mwanza Region

Some commonalities exist between these communities and the hazards to which they are exposed, along with their vulnerabilities and coping capacities. Combining this with secondary information, it is possible to generalize the climate risks across the region.

The key climate hazards faced by these three communities relate to variations in rainfall. This includes floods triggered by heavy rainfall, and periods of water scarcity. Variations in rainfall are also linked to landslides and cases of waterborne diseases such as cholera, and vector-borne diseases such as malaria. Communities also identified the spread of agriculture pests as potential climate hazards. Fishing communities described the climate impacts on fish catches, and the risk of storms.

Communities are exposed to these hazards. Many houses and facilities are built in high-risk zones. In one community, damage was witnessed to housing constructed within the flood zone, demonstrating the inability to either demarcate or enforce protected zones. Communities were also exposed to water scarcity through a lack of good quality water infrastructure. Communities often relied on 'traditional' water sources that dried up during dry periods, which could cause health problems.

Communities are vulnerable when exposed to these hazards. Climate information, which could allow communities to make decisions on short- to long-term scales, is lacking. Risks arise due to poorly constructed houses. For example, mud-brick walled houses are highly vulnerable to flood waters, and roofs are prone to be damaged during high winds. Fishing boats are unstable in stormy conditions on the lake. Poverty and the need to create livelihoods increases vulnerability, as does the lack of protective or social services. Some community members do not receive sufficient support from the government once a disaster happens, and families may

take years to recover. Persistent poverty and a lack of diversified, reliable income sources are a component of the vulnerability to climate hazards.

This assessment demonstrates that climate change and climate hazards are intermingled with ENRM. In Kayenze, participants reported how they had moved to the Lakeshore from other regions to seek economic opportunity, placing greater pressure on local resources. Influxes and movements by pastoralists also add to the pressure on resources. Wetlands have become encroached, forests deteriorated, and conflicts have arisen between different groups. World Bank research has identified that the basin is likely to be a hotspot of climate-induced migration, which could exacerbate these problems, and cause increased exposure to hazards and increased vulnerability (Kumari Rigaud et al., 2018). Agriculturalists concerned by changing pest patterns may be tempted to increase the use of pesticides, which could increase the non-point source pollution loads reaching the Lake. Polluting industries adjacent to watercourses can lead to increased point source pollution. Increased flood and erosion risks are linked to land-use changes, which is linked to limitations in land-use planning and enforcement.

The collection and analysis of hazard data conducted in the literature review suggested that these climate risks were widespread across the basin. As a result of climate change, these risks may well increase. Heavy rainfall is predicted to increase, and rainfall may become more variable with changes to the duration and the start of the rainy seasons, which will affect water and food security. These climate hazards are likely to be exacerbated by the increasing population which will expose a greater number of people and assets to these climate risks. These increasing climate risks are likely to place greater strains on ENRM and highlight the need for climate resilient ENRM.

This and the preceding chapter have demonstrated that communities in the LVB are vulnerable and have already faced negative consequences of climate hazards. As climate change continues, these impacts will be intensified.

5 Institutional Arrangements for Climate-Resilient Environment and Natural Resource Management: A Gap Analysis

This Chapter analyzes the LVB's institutional arrangements in place and identifies the gaps that need to be addressed through climate resilient investment programs. Institutional arrangements in this study refer to a collection of organizations, policies, strategies, regulations, and development plans, programs and projects.

5.1 Regional institutional arrangements for Climate Resilient ENRM

Regional organizations

The East African Community (EAC) is the principal intergovernmental organization that consists of the five LVB countries and South Sudan. The founding treaty (of 2000) establishes the EAC's mandate to cooperate on Environmental and Natural Resources Management. Within the EAC, the Climate Change Coordination Unit was established in 2017 as a specialized technical unit, supported by a Technical Working Group.

The Lake Victoria Basin Commission (LVBC) and the Lake Victoria Fisheries Organization (LVFO) are specialized regional institutions under the EAC. The LVBC's vision is for "a prosperous population living in a healthy and sustainably managed environment providing equitable opportunities and benefits." Its mission is "to promote, facilitate and coordinate activities of different actors in the LVB." The LVFO's mandate is to coordinate the regional management of fisheries and aquaculture resources.

Other key regional organizations include the Nile Basin Initiative; Intergovernmental Authority on Development Climate Prediction and Application Centre (ICPAC), and Regional Centre for Mapping of Resources for Development (RCMRD). Other organizations working in the region include Famine Early Warning Systems Network (FEWSNET), and the UN Environment Program (UNEP).

Regional policies

The EAC adopted a Climate Change Policy in 2011, to "contribute to the sustainable development in the EAC region through harmonized and coordinated regional strategies, programs and actions to respond to climate change." The Policy's focus is to create an integrated and harmonized framework for responding to climate change and highlights some priority action areas in adaptation and mitigation. The EAC Climate Change Strategy set out actions needed to fulfill this policy for the period 2011/2012 to 2015/2016, and the EAC Climate Change Masterplan set out a longer-term set of actions (from 2011 to 2031). The EAC published its Lake Victoria Basin Climate Change Adaptation Strategy and Action Plan 2018-2023 (LVBC, 2018), which identified priority investment areas. The LVBC also has coordinated policies on water resources and fisheries.

Regional projects and programs

Some notable programs have intended to address climate change adaptation and resilience in the basin. The Lake Victoria Environment Management (LVEMP) Project, financed by the World Bank, has been the flagship ENRM project in the Basin. LVEMP was implemented in two phases from 1995 to 2005 and from 2009 to 2017, respectively. LVEMP made investments

focusing on regional institutional strengthening, point-source pollution management and watershed management.

The Planning for Resilience in East Africa through the Policy, Adaptation, Research and Economic Development (PREPARED) project, funded by USAID, ran from 2012 to 2018. This project worked in the basin to build the capacity of organizations and communities. It had some notable outputs, including a climate risk assessment for East Africa and the Lake Victoria Basin, and the development of the Lake Victoria Climate Change Adaptation Strategy and Action Plan 2018-2023 (LVBC, 2018). This project resulted in knowledge products that have been useful references for this study, particularly in relation to basic climate information, and vulnerabilities in sectors such as agriculture, water and aquatic ecosystems, terrestrial ecosystems, health and sanitation, and infrastructure.

A key ongoing project is the Adaptation Fund-financed “Adapting to Climate Change in Lake Victoria Basin in Burundi, Kenya, Rwanda, Tanzania and Uganda” program from 2018 to 2020. The implementing entity is UNEP and the LVBC is the executing entity. Expected outcomes include (i) strengthened institutional and technical capacity to integrate climate resilience into transboundary water catchment management; (ii) improved delivery of accurate and timely climate information; (iii) climate change adaptation technologies; (iv) innovative, community-based projects; and (v) improved knowledge management frameworks.

There have been a number of lessons learned from prior investments, most notably from LVEMP. Its project completion report stated that without the project, “the water quality and ecosystems in the lake would likely have declined more rapidly, watersheds would be more seriously denuded, and the spread of waterborne disease would be more rampant ... Investments in sanitation, cleaner production, and water hyacinth control have impacted the management of point source pollutants and the symptoms of eutrophication.” The project report recognized that substantial challenges remain, due to the size of the basin and the financing and time needed to address all of these challenges. Therefore, realistic ambitions should be set. Next, the report concluded that consensus building around the use of shared resources, and the strengthening of regional institutions will take time, as many of the organizations, such as the LVBC, are relatively new. Being selective and sequencing investments was considered critical. The report noted that limited investment resources were spread across large sub-basins which reduced their impact. The report also noted that ownership, and community ownership in particular, was important to the success of investments and their sustainability. Lastly, the project completion report noted the need for basin wide investments in monitoring. While LVEMP made some important investments in this area, gaps in monitoring have reduced the ability to understand the baseline and the impacts of some investments.

5.2 National institutional arrangements for ENRM and climate change

National organizations

Burundi, Kenya, Rwanda, Tanzania, and Uganda have all established organizations and an institutional framework for ENRM and climate change. These include Burundi’s Ministry of Environmental Protection, Kenya’s Ministry of Environment and Forestry, Rwanda’s Ministry of the Environment, Tanzania’s Division of the Environment, coordinated by the Vice President’s Office, and Uganda’s Ministry of Water and Environment. Executing agencies include Kenya’s National Environmental Management Authority, and the Rwanda

Environmental Management Agency. Detailed policy committees have been established in some cases. In Kenya, the National Climate Change Council was founded in 2016. This body is headed by the President and supported by a Climate Change Directorate. In Tanzania, The Vice President's Office serves as the National Climate Change Focal Point and is assisted by the National Climate Change Steering Committee and the National Climate Change Technical Committee. In Uganda, a National Climate Change Advisory Committee, chaired by the Minister of Water and Environment, is supported by the National Climate Change Commission

National policies and programs

The network of organizations is supported by a series of national strategies and policies designed to address ENRM and climate change. Each country has a strategy for supporting long-term economic and social development (e.g. Kenya Vision 2030, Tanzania Development Vision 2025, and Uganda Vision 2040, which are combined with five-year plans. In relation to climate change specifically, Kenya has a medium-term Climate Change National Adaptation Plan (2015 to 2030) and has produced its second Climate Change Action Plan (2018 to 2022). Tanzania developed its National Climate Change Strategy in 2012, which superseded its National Adaptation Plan of Action (2007), and Uganda has its National Climate Change Policy (2015). Each country is a signatory of the Paris Climate Agreement and has developed Nationally Determined Contributions to tackle climate change. These national policies are supported by strategies and policies across such sectors as agriculture, land, and energy. The institutional arrangements described above are largely the result of national legislation (e.g. Kenya's Climate Change Act (2016), and Tanzania's National Environmental Management Act (2004). Each country has some ongoing programs for climate resilient ENRM in different formats. For example, Kenya has the Kenya Climate Smart Agriculture Project, and the Kenya Water Security and Climate Resilience Project, both supported by the World Bank. These various policies provide the framework and guidance for climate actions.

5.3 Gap analysis

Approach

An analysis of the institutional gaps and needs was conducted through literature review and engagement with stakeholders from the LVEMP NPCTs. This study adopted two theoretical frameworks that have been developed and applied for assessing the adaptive capacity of organizations and communities: (i) National Adaptive Capacity Framework (NAC) (Dixit et al., 2012) and (ii) Local Adaptive Capacity Framework (LAC) (Africa Climate Change Resilience Alliance, 2010).

The NAC Framework explores whether national organizations are able to adapt to climate change. It frames national adaptive capacity as consisting of five institutional functions that include: (i) the assessment of risks and vulnerabilities to guide decision making; (ii), the prioritization of needs and measures; (iii) the coordination of different actors; (iv) the management of information; and (v) the management of climate risks (Dixit et al., 2012). This framework was applied to the analysis of LVBC, Kenya, Tanzania, and Uganda.

The LAC Framework similarly addresses five characteristics at the local level. These are (i) the asset base; (ii) institutions and entitlements; (iii) knowledge and information; (iv) innovation; and (v) flexible, forward decision-making (Africa Climate Change Resilience Alliance, 2010). The LAC framework was only applied to Tanzania, where a stakeholder group was convened

to consider these factors. These frameworks were applied following engagement with the National Project Coordination Teams (NPCTs), or in the case of the LVBC, the Regional Project Coordination Team, through a workshop setting. In Kenya and the LVBC, meetings were held with the NPCT. Uganda was principally addressed through desktop review of the existing documents. Tanzania was addressed in more depth using both the NAC and LAC frameworks because of the study's engagement in the Mwanza Region. Full details of the analysis are provided in Technical Report 3. The purpose of the gaps and needs analysis is to support the identification of measures that are then subsequently prioritized, following the approach described in Chapter

Results and discussion

The analysis separately explores institutional gaps and needs of the LVBC as well as riparian countries Kenya, Tanzania, and Uganda. There are some commonalities among them. For the sake of clarity, a distinction is made between the gaps and needs of regional and national bodies.

Regional Coordination

The LVBC, a regional institution of the EAC, has an important role to play in addressing climate change risks, although there is unclarity surrounding the LVBC's role in relation to climate change action. The 'Protocol for Sustainable Development of LVBC' ('The LVBC Protocol') states the duty to cooperate on the environment, sustainable development and technical area such as meteorological services. However, as described previously, the EAC has a coordination unit focused on climate change. The LVBC Strategic Plan 2016 – 2021 includes addressing climate change as a development objective. This is supported through the various policies and action plans described above. The LVBC and the EAC should review and coordinate climate related policies. This would mean ensuring that the implicit role of the LVBC to address climate change included in the LVBC Protocol is clarified, and the responsibilities on action are placed or shared between the most appropriate organizations.

Second, there is a need to strengthen coordination and sharing of knowledge and information at the regional level, and knowledge is currently shared across several agencies. A central hub could be developed as a focal point for this information. Early Warning Systems could also be strengthened through regional cooperation. In addition, the LVBC and EAC should develop their role in the management of knowledge and information. This should be aligned with the appropriate policy framework, financial resources, and technical capacity to carry out this role.

Third, the LVBC has the LVB Climate Change Adaptation Strategy and Action Plan 2018-2023. However, no sustainable financial mechanism exists to ensure that the plan is monitored and evaluated, and then revised and updated for the period post-2023. There is a need to put policy in place to ensure regular monitoring of the climate change action plan, and the requirement to update this plan on a regular basis. This should be supported by financial and technical resources.

National governments

First, each of the national governments have developed institutional frameworks for tackling climate change that is supported through policies, and legislation. However, there is a need to strengthen coordination between the agencies responsible for addressing climate change issues.

Coordination between different sectors and different hierarchical levels (government ministries down to regions, districts and villages) should be strengthened.

Second, climate considerations have not yet been mainstreamed in many activities and programs, despite high-level strategies and plans. An example of this is the challenge to periodically update the regional climate change adaptation plan and action strategy. In the environmental sector, the mainstreaming of climate change activities should focus on areas such as promoting climate resilient agricultural practices, improved urban development, and action to tackle pollution. Participatory planning approaches that incorporate women and other vulnerable groups could be adopted to improve mainstreaming and enhance access to land resources.

Third, the management of, and access to knowledge and information remains a challenge at all levels. On one hand, policy makers report gaps in information that can be used for practical decision making, and communities lack knowledge on the risks that they may face, and how they may best respond to them. There is a need to improve this through activities including data collection and monitoring systems, the creation of knowledge hubs, support for policy-linked research, early warning systems, and knowledge dissemination initiatives. Risk and vulnerability assessments should be conducted at the local scales relevant to communities. Across the basin, there is a need for greater capacity building at all levels—from central government down to local government, and further down to community levels—through activities like farmer field schools or sensitization campaigns.

Fourth, at the local or community levels, some of these aforementioned gaps are compounded. Access to resources can be challenging during disaster or climate shocks, and access may not be shared equitably. These might be short-term resources to recover from shocks, or other forms of finance to support innovation. Women and other disadvantaged groups may face particular problems in this regard. Institutional analysis conducted during fieldwork in the Mwanza Region of Tanzania identified a lack of participatory planning, which meant that communities were disconnected from decision making. Greater participatory planning could promote ownership in investments, as well as strengthen capacities at local levels.

6 Identification and Assessment of Climate-Resilient Investment Interventions for the Lake Victoria Basin

Built upon the results of the climate risks and institutional assessment as well as ENRM activities supported by regional and development programs or projects, this chapter first puts together a set of ENRM interventions in LVB and then uses the climate resilience assessment methods introduced in Chapter 2 to assess their contribution to climate resilience.

6.1 Identifying potential ENRM measures for assessing climate resilience

The starting point of this assessment was to prepare a relatively comprehensive list of ENRM options as the candidates for CR assessment. As discussed earlier, climate change has the potential to affect every sector within the basin. As this study aims to identify investments that contribute to climate resilient ENRM, the investment interventions listed for CR assessment are primarily those which have the potential to improve ENRM. As water pollution and lake eutrophication have been prominent and transboundary environmental problems in the LVB and are the priority of the regional environmental management efforts, the list of proposed investments is focused on strengthening institutional capacities for regional collaboration, SLWM for cutting soil erosion and sediments from non-point sources pollution, and municipal and industrial pollution control.

The list of ENRM investments was prepared through the review of existing environmental and climate strategies, plans, programs and projects that have been developed at regional and national levels across the LVB. Some of them were described in Chapter 5. The relevant plans reviewed also include national documents such as Kenya's National Adaption Plan, Tanzania's National Climate Change Strategy, and Uganda's National Climate Change Policy. They also include the results of the assessment of institutional gaps and needs in Chapter 5 and recent analytical works such as the Country Environmental Analysis which identified the need for investments such as the promotion of resilient landscapes and improved pollution management through strengthened institutions (World Bank, 2019b). In addition, several specialized guidance reports, such as on Climate Smart Fisheries (IFAD, 2014), Climate Smart Agriculture (e.g. Bell et al., 2018), and Sustainable Land Management (Liniger et al., 2011) were reviewed.

The list of measures also includes those investments financed by LVEMP Phase I and Phase II and proposed for future financing. Phase I supported the activities in fish resource management, hyacinth control, industrial pollution management, and improved land-use and policy frameworks. Phase II expanded the support to institutional capacity including the development of harmonized policies in water and fisheries management, point source pollution including municipal wastewater treatment, sanitation management, and industrial wastewater control in selected hotspot areas, and integrated watershed management including sustainable land management, wetland and water buffer zone protection, and improved livelihood schemes.

As a result, ENRM measures in LVB are grouped in the following three broad categories: institutional support; non-point source pollution control, and point-source pollution control. Investments identified in the three categories are presented below. More details on specific investments are presented in Appendix 3.

Institutional support to transboundary cooperation, institutional strengthening, information sharing, and knowledge management

A lack of adequate institutional arrangements and weak capacity have impeded successful project implementation, monitoring, and evaluation. The main thrust of this group of technical assistances is to support overall strategy development, long-term planning, and investment plan of ENRM and climate investments in the basin, strengthen institutional capacity, share information and knowledge across countries, and enhance regional collaboration and monitoring at regional and national institutions. The need to monitor environmental conditions and share knowledge was highlighted in the lessons learned from LVEMP. Weaknesses in this area make it very difficult to establish a baseline. Monitoring investment progress and results can include support for monitoring equipment, training, and human resources to implement monitoring programs. The interventions in this category are summarized below:

- Planning, strategy, and financing
 - Revise and develop a regional Climate Change Adaptation and Mitigation Strategy and Action Plan.
 - Develop a regional investment plan for wastewater and sanitation, improved water quality and ecosystem services.
 - Develop a strategy for resource mobilization, and the tracking of finances.
- Policies, regulations, and guidelines
 - Finalize the New Water Release and Abstraction Policy for the LVB.
 - Develop climate-resilient catchment management plans.
 - Develop guidelines and best practices for integrating climate resilient design practices into infrastructure planning.
 - Strengthen implementation and enforcement of regional policies on good fisheries practices.
- Research, monitoring, and knowledge management
 - Strengthen and enhance environmental monitoring and the collection of data
 - Strengthen and enhance the management and sharing of data and knowledge.
 - Support research and assessments of existing and emerging environmental and climate issues.
 - Develop and strengthen Early Warning Systems and DRM.
- Institutional and capacity development
 - Participate in the development of sustainable funding mechanisms for regional bodies.
 - Strengthen partnerships between LVBC and other institutions within the Basin, including technical capacity development.
 - Build capacity for research and monitoring of environmental and climate conditions.
 - Support basin-wide knowledge transfer through dissemination of best practices.

Addressing non-point source pollution through SLWM practices

The measures in this category address land, wetland, and forestry degradation, which are problems in themselves, and non-point source pollution which is linked to high rates of sediment transport and increased nutrient loads deposited into the Lake, which results in

eutrophication and water hyacinth and algal blooms. Hyacinth removal and national action on fisheries management are also included under this group.

Sustainable Land Management (SLM) is the use of land resources including soil, water, vegetation and animals to produce goods and provide services to meet changing human needs, while ensuring the long-term productive potential of these resources and the maintenance of their environmental functions (Liniger et al., 2011). Here, the term SLM is modified to reference Sustainable Land and Water Management (SLWM), covering wetland and water buffer zone protection and making explicit the important relationship between land and water.

SLWM measures can be categorized based on their applied technologies and adopted approaches. WOCAT (2007) divides Sustainable Land Management measures into four categories: Agronomic, vegetative, structural, and management measures. Agronomic measures refer to techniques that improve soil cover and enhance organic matter and soil fertility. Vegetative measures refer to techniques such as agroforestry, and planting shrubs to reduce soil land degradation. Structural measures include the construction of terraces and water storage. These are sometimes referred to as physical measures. Management measures include zoning, changes in land use, and the timing of agricultural activities. Taken as a whole, SLWM measures can reduce flood risk for communities by increasing storage and infiltration and reducing fast surface runoff.

In practice, SLWM techniques are typically implemented as a package that combines agronomic, vegetative, structural and management measures. For example, terracing, while primarily seen as a structural measure, may involve planting vegetation to strengthen soil structure, employing low-tillage techniques and using organic mulches to enhance soil fertility. Under this broad category, measures that address fisheries management and aquatic weed control are also included.

- Agronomic measures, including conservation agriculture and integrated soil fertility management
- Sustainable forest management, agro-forestry, and silvo-pastoralism
- Rainwater harvesting
- Integrated watershed management
- Cross-slope barriers
- Integrated crop-livestock management and rangeland management
- Aquatic weed control
- Fisheries management
- Innovative financing and support for livelihoods
- Institutional and capacity development at district and community levels

Addressing point source pollution produced by industrial and municipal waste

Point source pollution from municipal and industrial sources has been identified as a major problem that diminishes water quality in Lake Victoria. An earlier analysis of LVEMP estimated that 48% of the external BOD load came from industry and municipalities, with the remaining coming from catchment runoff (Kayombo and Jorgensen, 2003). This category includes investments that address the design and construction of improved infrastructure, particularly in the sanitation and solid waste management sector. It also includes support for improved industrial processes through resource efficiency and cleaner production practices.

There is a role for green infrastructure or nature-based solutions in addressing pollution risks enhanced by climate change. Lastly, there is a significant focus on the improved monitoring of discharges and resulting water quality, both at the local or national scale, and by supporting joint regional monitoring efforts. The following measures are considered:

- Infrastructure for sanitation and waste management
 - Develop and implement sanitation master and pollution prevention plans.
 - Feasibility studies, design, and construction of ‘green’ and ‘gray’ infrastructure
 - River improvement schemes
 - Improved collection and disposal services for solid waste.
- Improved industrial waste management
 - Technical advisories to support in-plant Resource Efficient and Cleaner Production (RECP) practices
 - Promote cleaner and renewable technologies
- Regulations, policies, and guidelines for municipal and industrial waste management
 - Enforce laws on urban planning and storm water management in urban areas;
 - Strengthen regulatory and incentive systems for pollution control
 - Promote Environmental Impact Assessments for new investments
- Research, monitoring, and knowledge management
 - Water quality monitoring and discharge assessments
 - Support national level efforts to share data on water quality and quantity
 - Conduct research between water quality and climate
- Capacity and institutional strengthening for municipalities and enforcement agencies
 - Institutional strengthening for enforcement agencies
 - Enhance capacity of institutions and bodies responsible for water and sanitation
 - Raise awareness on Regional Industrial and Municipal Effluent discharges

6.2 Assessing the contribution of potential ENRM measures to enhance climate resilience

This section outlines the results of assessing the contribution of investments to enhance climate resilience, following the methodology presented in Chapter 2. Appendix 4 presents the full results that link investments to attributes.

Before describing the analysis, a few examples are provided of how attributes can be linked to investments, and how the basin can better manage climate risk and environmental management. This list, presented in Table 5, is not intended to be exhaustive.

Table 5. Attributes of climate resilience and examples of contributing investments

Attribute	Example of investment	Potential benefit to LVB and Climate Resilience
Robustness	Protection of gullies Cross-slope barriers Climate resilient water and sanitation infrastructure	Reduced likelihood of flooding, which would lead to point and non-point source pollution.

Learning	Capacity development and training Improvement of knowledge management systems Data collection, monitoring, and research	Increased uptake and effectiveness of climate resilience measures such as SLWM. Improved knowledge on where to apply measures for maximum effect.
Inclusion	Participatory planning processes Programs that prioritize disadvantaged groups in accessing resources	Increased ownership of communities in implementing measures and increased likelihood of implementation and enforcement. Reduced likelihood that disadvantaged groups will implement unsustainable activities during times of distress.
Flexibility	Adaptive water resources policies and plans Support for alternative income source	Increased ability of communities to implement measures that address different climatic situations (e.g. periods of extreme dry or wet weather). Reduced need for communities to implement unsustainable activities in times of distress.
Self-Organization	Development of climate change adaptation plans Strengthening of regional Coordination	Increased ability of multiple levels of government (e.g. catchment level or EAC) to develop and implement policies that Better response to climate change.

Institutional support to transboundary cooperation, institutional strengthening, information sharing, and knowledge management

It is not possible for the report to demonstrate all the resilient pathways that may be supported by investments presented above. Instead, a few resilient pathways are identified and explored.

Investments in planning, strategy, and financing, in the form of an updated Climate Change Adaptation and Mitigation Strategy and Action Plan, or investment plans to improve sanitation or water quality, are likely to directly support *self-organization*, and the ability of regional organizations to identify problems, prioritize solutions and mobilize resources. The development of these plans requires the assessment of existing interventions and their effectiveness, which will support *learning*. Furthermore, these plans should be *flexible*, in that they should be able to cope with an uncertain future. Indirectly, if these investment plans come to fruition, they may support the robustness of environmental systems, and therefore absorptive capacity. This pathway is shown in Figure 6.

Figure 6. Potential resilient pathway for investments in regional planning, strategy, and financing

Policies, regulations, and guidelines can also create pathways to resilience. In the case of catchment management planning, guidelines and policies can create the possibility of strengthening **robustness** by promoting practices that better withstand climate extremes such as the planting of trees and protection of wetlands. **Learning** and **inclusion** can be enhanced through ensuring the participation of communities in the development of policies and guidelines. Such participatory planning can foster the conditions for **self-organization**, where catchment users can effectively make and enact decisions. Lastly, guidelines and policies for catchment management can support the adoption of **flexible** approaches that respond to uncertainty by supporting the adoption of practices such as rainwater harvesting or designating alternative water supplies.

Research, monitoring and knowledge management investments are particularly strong in supporting **learning** and **self-organization**. Examples of this include monitoring environmental conditions and undertaking research that builds the knowledge base for action. These can strongly support the development of adaptive capacity, although the relationship can be considered more indirect, with the long-term effects appearing later. Effective knowledge management measures can support inclusion and the know-how to enable the adoption of techniques that support the ability to withstand climate shocks (i.e. **robustness**).

Lastly, these institutional and capacity development measures can support **learning** and **self-organization**. An example of such measures is the support for enhancing technical capacity within regional bodies with responsibility for climate action and ENRM (i.e. the LVBC). Depending on the extent of this capacity building, it can directly lead to enhanced **robustness** and **flexibility**. An example of this is regional support for knowledge dissemination and best practices. Capacity building on climate-smart land and water management practices at the community level can contribute directly to enhanced **inclusion**.

Considering adaptation, some of the activities that link most strongly and directly are investments such as support for climate resilient catchment management plans, and support for

knowledge transfer across the basin, in ways that permit the implementation of best-practices in the field. The measures described in this component generally have weaker links to mitigation because a lot of the focus is on adaptation and on creating the conditions that support action, rather than directly supporting on-the-ground activities that could result in mitigation. The results of the analysis of this group of investments is presented in Table 6.

Table 6. Assessment of proposed institutional measures

Option	Resilience	Adaptation	Mitigation
<i>Planning, strategy, and financing</i>			
Revise and develop a regional Climate Change Adaptation and Mitigation Strategy and Action Plan to supersede the existing Plan for the period 2018 to 2023.	++	++	+
Develop a regional investment plan for wastewater and sanitation, improved water quality and ecosystem services.	++	+	+
Develop a strategy for resource mobilization, and the tracking of finances.	++	+	+
<i>Policies, regulations, and guidelines</i>			
Finalize the New Water Release and Abstraction Policy for the Lake Victoria Basin.	++	++	+
Develop climate-resilient catchment management plans. This could be combined with the development of Transboundary Water Resource User Associations (TWRUAs).	+++	+++	++
Develop guidelines and best practices for integrating climate resilient design practices into infrastructure planning.	++	++	0
Strengthen implementation and enforcement of regional policies on good fisheries practices.	+++	+	+
<i>Research, monitoring, and knowledge management</i>			
Strengthen and enhance environmental monitoring and the collection of data	+	+	+
Strengthen and enhance the management and sharing of data and knowledge.	++	++	+
Support research and assessments of existing and emerging environmental and climate issues.	+	++	+

Develop and strengthen Early Warning Systems and DRM.	+++	++	0
<i>Institutional and capacity development</i>			
Participate in the development of sustainable funding mechanisms for regional bodies.	+	+	+
Strengthen partnerships between LVBC and other institutions within the Basin, including technical capacity development.	++	++	+
Build capacity for research and monitoring of environmental and climate conditions.	+++	++	+
Support basin-wide knowledge transfer through dissemination of best practices.	+++	+++	+++

Addressing non-point source pollution through SLWM practices

SLWM techniques are likely to support climate resilient measures. Figure 7 presents an example of such a pathway for agronomic measures which includes measures like supporting cover crops, low-tillage techniques and integrated soil fertility management. These techniques are designed to enhance **robustness** to extreme weather conditions by enhancing the ability for soils to retain their structure, water content and nutrients. By definition, such measures should be implemented as a package that provides communities with **flexibility**, through a variety of options. These measures are not well practiced individually. By nature of how they are implemented at community levels, they should be implemented in partnership with the community, so as to support **inclusion**. This can result in enhancements to absorptive, adaptive and transformative capacity.

Figure 7. Potential resilient pathway for investment in agronomic measures

Many of the SWLM techniques support **robustness** to climate extremes. Further examples of this include rainwater harvesting techniques that can support communities during dry periods,

and planting trees that can reduce the risk of flooding. SLWM techniques across the board are typically designed to support *flexibility*, *learning*, and *inclusion*, with some offering more flexibility than others. In the case of cross-slope barriers, high costs can be involved with their construction, and once built, they may only strengthen a small number of attributes - to support robustness and inclusion. However, this does not mean that it is not worth pursuing. These attributes can contribute to absorptive and adaptive capacity by reducing runoff and landslide risk, retaining soil, and including the community in their management. Integrated crop and livestock management techniques, on the other hand, can be implemented more flexibly. Finally, some of the techniques such as those targeting climate smart fishing can be implemented through groups such as the Beach Management Units (presented in Chapter 4) and therefore strengthen *self-organization*. It's worth acknowledging that some investments may score low on resilience due to the limited number of attributes they contribute to strengthening, rather than the extent to which they contribute. Cross-slope barriers on their own do not necessarily lead to improvements in flexibility or inclusion, although this can depend on how they are implemented.

As most of these measures result in on-the-ground activities, in terms of adaptation they can be particularly effective. The planting of forests can be particularly effective in supporting adaptation to climate extremes such as heavy rainfall. Under dry conditions, WOCAT considers rainwater harvesting to be strongly effective. Some of these measures are also thought to strongly support mitigation, especially the planting of trees and agronomic measures. The latter can help soil perform its role as a carbon store. The results of the analysis of this group of investments in presented in Table 7.

Table 7. Assessment of proposed investments addressing non-point source pollution through SLWM practices

Option	Resilience	Adaptation	Mitigation
Measures			
Agronomic measures	++	++	++
Sustainable forest management, agro-forestry, and silvo-pastoralism	+++	+++	++
Rainwater harvesting	++	+++	+
Integrated watershed management	+++	++	++
Cross-slope barriers	+	++	++
Integrated crop-livestock management and rangeland management	+++	++	++
Aquatic weed control	+	0	+
Fisheries management	+++	++	+

Approaches			
Financing and improved livelihoods	+++	++	+
Institutional and capacity development	+++	++	++

Liniger et al. (2011) provides information on the potential benefit-costs of SLWM measures. This shows that there is a significant difference between the short and long-term benefit-cost ratio between investments. For example, bench terraces can be costly to construct and their benefits develop only over the longer-term. However, in the long-term, the research has demonstrated that the investments with the greatest long-term benefit-cost ratios were agronomic measures (in the form of improved soil and vegetation cover, improved soil treatment, such as low-tillage systems, and integrated soil fertility management), and rainwater harvesting in the form of either improved catchment management or rooftop systems. None of the identified measures were found to have negative benefit-cost ratios in the longer-term. These figures should be considered with some caution. The guidance was prepared for Sub-Saharan Africa, however in practice the actual costs will vary from site to site.

Addressing point source pollution produced by industrial and municipal waste

The category presents good opportunities to integrate the principles of climate resilient design into infrastructure development for risk reduction of climate-induced pollution incidents, such as incorporating flood risk into the design of wastewater treatment plants and solid waste management facilities and taking account of increased rainfall into the stormwater drainage infrastructure. Smart interventions in solid waste management can also reduce flood risk for communities. Some of the measures in this category are linked to greenhouse gas mitigation through increased resource efficiency.

Figure 8 shows that infrastructure for sanitation and waste management can lead to resilience through enhancements in *robustness* and *flexibility*. Well-designed infrastructure should be able to cope with climate extremes such as heavy rainfall and flooding. In addition, well-designed infrastructure should be designed so that it can operate under a range of climate conditions, by being able to respond to changing weather. Such flexibility and robustness can lead to absorptive and adaptive capacity.

Figure 8. Potential resilient pathway for investments in infrastructure for sanitation and waste management

Improved industrial waste management, under the guise of RECP, can also strengthen **robustness** by developing processes that are less likely to be polluting under extreme weather. The nature of these investments, through their use of innovative techniques, are likely to require training, and therefore support **learning**. Such training can promote participation and **inclusion**.

Regulations, policies, and guidelines for municipal and industrial waste management are primarily targeted at strengthening **robustness** by ensuring that protective measures are put into place. Research, monitoring, and knowledge management of municipal pollution is strongly linked to investments on transboundary cooperation around pollution and research assessed earlier in this section. This research supports **learning** and can underpin action to create **robustness**. In itself, it supports **self-organization** by creating the foundation for relevant agencies to take action. In the LVB, these include water utilities, municipal entities, and environmental protection agencies. Lastly, investments in capacity and institutional strengthening for municipalities and enforcement agencies should lead to more **robust** practices to reduce climate induced pollution. This clearly goes hand-in-hand with action to support **learning** and **self-organization**. Taken as a package of measures, these are likely to support the core capacities of absorptive and adaptive capacity. These measures are potentially transformative if sustainably and broadly applied. The results of the analysis of this category of investments are presented in Table 8.

Table 8. Assessment of proposed investments addressing point source pollution

	Resilience	Adaptation	Mitigation
Option			
Infrastructure for sanitation and waste management			

Develop and implement sanitation master and pollution prevention plans with a focus on climate change and extreme weather events.	+++	+	+
Feasibility studies, design and construction of infrastructure for municipal water and stormwater management, incorporating principles of climate resilient design.	++	+++	+
River improvement schemes that contribute to reduced flood risk and discharge of pollutants.	++	+++	0
Improved collection and disposal services for solid waste.	++	++	++
Improved industrial waste management			
Technical advisories to support RECP with a focus on climate adaptation and mitigation.	++	++	++
Promoting cleaner technologies through financial support, including grants.	++	++	++
Regulations, policies, and guidelines for municipal and industrial waste management			
Enforce laws on urban planning and storm water management in urban areas.	++	++	+
Strengthen regulatory and incentive systems for environmental pollution control and prevention.	++	++	++
Promote Environmental Impact Assessments for new infrastructure and industrial investments.	+++	++	++
Research, monitoring, and knowledge management			
Water quality monitoring and discharge assessments.	+	++	0
Support national level efforts to share data on water quality and quantity nationally and regionally.	++	++	0
Conduct research to link regional water quality monitoring with climate observations to underpin knowledge of climate impacts on water quality.	++	++	0
Capacity and institutional strengthening for municipalities and enforcement agencies			
Institutional strengthening for enforcement agencies.	++	++	++
Enhance capacity of institutions and bodies responsible for water and sanitation on climate change impacts and the water sector.	++	++	+
Raise awareness on Regional Industrial and Municipal Effluent discharge into the river system and the Lake.	+++	++	+

To help understand and illustrate how climate resilient activities will interact with environmental and economic systems, the DPSIR framework, introduced earlier, is used.

Figure 9 shows how climate change adds to the existing pressures and can adversely affect the state of the environment. For instance, climate change could change the lake's temperature profile, leading to decreased dissolved oxygen and a further reduction in fish stocks, although the complete understanding of these complex relationships is fragmented (Ogutu-Ohwayo et al., 2016). Measures to strengthen the transboundary management of water, land, and fish resources, through capacity building of the regional and national bodies, and better enforcement of existing regional and national policies, could mitigate the negative impacts arising from climate change. Similar pathways can be used in relation to unsustainable agricultural practices, which could be addressed through SLWM measures, and increased urban pollution, which can be addressed through improved monitoring and infrastructure.

Figure 9. Elaborated DPSIR framework with climate change and climate resilient response

These pathways, however, have some uncertainty as climate change may push environmental degradation in different directions. For example, while increased rainfall may increase erosion, it may also dilute suspended sediments. In addition, these pathways can be complicated by potential feedback on how climate change could alter drivers and pressures in unexpected ways. The relationships presented in Figure 9 represent potential state changes and impacts that could be exacerbated by climate change. Detailed modelling of the entire climate, environmental and

economic systems will be necessary in order to quantitatively help the impacts of climate resilient interventions.

7 Recommendations and the Way Forward

7.1 Recommended investments

The final recommendations for climate resilient ENRM measures in the Lake Victoria Basin are summarized in the section and they are grouped in the same three categories introduced in Chapter 6.

Enhanced transboundary cooperation on environmental and natural resources management.

Enhanced transboundary cooperation is critical to building climate resilience through promoting polycentric governance and coordination between entities with overlapping responsibilities. Transboundary cooperation recognizes the Lake Victoria Basin as a complex, dynamic system. Investments in transboundary cooperation also encourage learning, knowledge generation and knowledge transfer in relation to building climate resilience. The recommended interventions include:

Enhanced regional planning: Regional bodies should be supported to coordinate actions on climate adaptation and mitigation, and to develop regional strategies and action plans on mitigation and adaptation that extend beyond 2023. Regional investment planning for improved sanitation and ecosystem services should be developed, with a focus on climate risks. This planning should be accompanied by resource mobilization strategies.

Improved enforcement and implementation of existing policies: The regional bodies, led by the EAC and the LVBC, have developed harmonized policies on areas that include water and fisheries resources management. Future investments should address the implementation of these policies with a focus on the importance of integrating climate adaptation activities.

Improved knowledge management and monitoring: Action on environmental management and climate risks must be underpinned by a strong foundation of data and knowledge. Improved collection and sharing of knowledge through regional platforms, as well as investments in high-quality weather and water monitoring hardware and systems underpin the building of climate resilience. The use of innovative, lower cost solutions such as satellite data and UAVs should be promoted. This knowledge will create the foundation for greater knowledge and research on the relationships between climate change and environmental degradation. This greater knowledge should be disseminated effectively through knowledge sharing mechanisms and publications such as the State of the Lake Report.

Improved Early Warning Systems (EWS): Well-designed EWS will be able to assist the governments and communities to increase the chance to reduce the loss of life and property caused by climate change-induced disasters in the LVB. This will require integrating climate resilient consideration into the design and investments of EWS which was intended to prevent and reduce water pollution incidents.

Institutional and capacity development: All of the investments described above should be underpinned with strong institutions with the technical capacity to address the challenges that climate change presents. The technical capacity of the LVBC and EAC will be enhanced through training. Capacity development should also be supported within national and local governments in the basin, and across the basin through exchange visits and other plans. The

region is home to several agencies with great expertise in climate adaptation and mitigation. It is important to support partnerships between agencies, such as ICPAC and RCRMD.

Addressing non-point source pollution through SLWM practices

SLWM management practices bolster efforts through the creation of landscapes and encourage practices that are robust defence mechanisms against the impacts of extreme events. They increase flexibility by providing alternative livelihood options for communities engaged in agriculture. Because of their implementation at the community level, they promote learning and knowledge creation, and encourage the inclusion of diverse groups, including vulnerable ones. The priority investments are:

Agronomic techniques: Conservation agriculture measures that combine enhanced soil cover, reduced or no-tillage techniques, integrated soil fertility management and integrated pest management, all contribute to climate resilience in dry and wet periods. These techniques enhance climate mitigation in addition to their contribution to adaptation and building resilience.

Agro-forestry, silvo-pastoralism, and community forest management in drylands: These techniques are among the most effective for reducing land degradation and enhancing climate resilience through adaptation and mitigation. The planting of trees can significantly contribute to mitigation due to their ability to sequester carbon. Large commercial sites typically have higher investment costs and may take longer to pay a return. Agro-forestry and silvo-pastoralism can be applied across the basin more widely. These techniques will also protect water resources, and provide multiple benefits such as flood risk management benefits by reducing the rate of fast runoff

Integrated crop-livestock management and rangeland management: Agronomic techniques and approaches such as silvo-pastoralism should be combined with integrated crop-livestock management and rangeland management. These approaches reduce land degradation and increase climate resilience through improved and diversified livelihoods.

Integrated water management and rainwater harvesting: Rainwater harvesting is a cost-effective measure that enhances climate resilience and can reduce land-degradation. High capital costs can be a barrier to engineered solutions, and in order to promote adoption, support should be provided to lower-cost rainwater harvesting measures such as in-situ techniques or micro-catchments. Another key investment that should be promoted to foster climate resilience is the protection and rehabilitation of wetlands and gullies.

Climate resilient fisheries management: Good practices should combine the development of protected zones with improved and targeted fishing techniques. Such techniques help to protect the breeding of species that are vulnerable to climatic changes. Capacity development and research—which includes a climate vulnerability assessment – also aid climate resilience. Support for livelihood diversification can remove pressure on scarce resources.

Community-level capacity and institutional strengthening for SLWM: Increasing capacity at the community level is vital to supporting SLWM. Such capacity development should target district officers and community members, with a strong focus on gender issues, by centering on women and other vulnerable groups within communities.

Addressing point source pollution produced by industrial and municipal waste: Point source pollution is one of the greatest threats to environmental health in the basin. Investments in sanitation and municipal waste management enhance climate resilience primarily by making the basin more resistant and robust towards climate shocks by reducing the pollution loads on the basin.

Investments in sanitation, stormwater and solid waste infrastructure: New investments such as wastewater treatment plants, storm water and solid waste management should have climate change and extreme events explicitly integrated in their design. These investments may be costly, but they have a significant impact on improving water quality and enhancing climate resilience by being better able to cope with extreme rainfall and reducing flood risk. ‘Green’ infrastructure should be promoted where possible, as these techniques are cost-effective and contribute to mitigation. One example is how constructed wetlands can reduce the risk of flooding, improve water quality, and sequester carbon dioxide.

Resource efficient and cleaner production: Investments in RECP have contributed to reduced pollution, and these efforts should be expanded with a greater focus on climate mitigation and adaptation. Adaptation should start by identifying and working with those industries at a higher risk of polluting the environment as a consequence of extreme weather events.

Improved monitoring and research on pollution: Efforts to reduce pollution should be coupled with greater monitoring and research investments to better understand the link between climate and pollution. This involves additional hardware, monitoring protocols and processes to share the data more broadly within countries and across the LVB.

Capacity development and institutional strengthening: Throughout this report, the importance of capacity and institutional strengthening has been identified as critical to supporting ‘hard’ investments. This applies to efforts to reduce point source pollution. These efforts could include training to raise the awareness of the links between pollution and climate risks, and efforts to strengthen enforcement capabilities for organizations working to monitor and control pollution and potential impacts of climate change.

If prioritization was based on environmental management alone, some of these proposed investments would have a lower chance of being prioritized and selected. These include efforts to support early warning systems and monitoring and researching the relationships between climate and the state of the environment. Other proposed investments might have been selected, but considering their CR contribution would put more emphasis on them. An example of this is the investment in constructing new sanitation and wastewater infrastructure incorporating CR design standards. While there have been investments in wastewater treatment facilities under LVEMP II, ensuring that these systems can cope with extremes of rainfall and temperature represents a shift in thinking towards climate resilience.

7.2 The way forward

Built on the CR assessment methods available in the literature, the report further proposed and adopted a practical method to qualitatively assess how various ENRM measures for LVB may contribute to climate resilience. The method selected five CR attributes, fewer than the nine or eleven used in RABIT or some other methods, to qualitatively assess a system’s absorptive, adaptive and transformative capacities that combine to constitute resilience to potential climate

change shocks. The CR assessment results will be useful for LVB countries in their efforts to select and prioritize their ENRM investment activities to enhance the basin's climate resilience.

However, as discussed earlier, the qualitative assessment method introduced in the report uses the number of attributes that ENRM measures contribute to score the impact and has its limitations. How to quantify and assess the magnitude of the impacts that ENRM measures have on reducing climate risks and building climate resilience would be an area of further study. Quantitative techniques and modeling could be carried out, although this would require good access to comprehensive data sets, multi-disciplinary expertise, and additional analytical work. The broader participation of experts could be used to help score and evaluate investment measures according to their contribution to CR. Furthermore, quantitative proxy indicators could be identified and used to form the basis of the results framework of investment projects.

As the Lake Victoria Basin is a vast and diverse area, further studies could be undertaken to assess CR effectiveness through various ENRM activities in specific study areas where factors such as topography, climate, soils, vegetation, existing infrastructure and institutional arrangements can be further analyzed and used.

Although important and highlighted in the report, CR is only one of the criteria in the evaluation and final selection of climate resilient ENRM measures and, others--technical, economic, financial, environmental, and social criteria among them--are equally important and should be applied during project appraisal.

Last but not least, while this study has highlighted what measures should be undertaken to enhance climate resilience, how the institutions can be incentivized to undertake action remains an open question. While this is beyond the scope of this study, a deeper institutional and political analysis could path the way to unlocking action on climate change in the Lake Victoria Basin.

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APPENDICES

Appendix 1 List of Supplementary Technical Reports

Technical Report No.1: Climate and Disaster Risks in the Lake Victoria Basin: A Literature Review

Technical Report No.2: Climate and Disaster Risk Assessment of the Lake Victoria Basin: A Case Study of Three Communities in Mwanza Region, Tanzania

Technical Report No.3: An Institutional Gaps Analysis for Promoting Climate-Resilient Environment and Natural Resource Management in the Lake Victoria Basin

Technical Report No.4: Assessment and Identification of Climate-Resilient Investment Interventions for the Lake Victoria Basin

Appendix 2 Additional information on SLWM management measures

Table A1. Contribution to land degradation and climate resilience for SLWM measures

Measure or approach	Land degradation	Resilience to dry conditions	Resilience to rainfall variability	Resilience to extreme rainfall and storms	Resilience to rising temperatures	Natural disaster prevention /	Adaptation mitigation /	Carbon sequestration
Agronomic measures: Integrated Soil Fertility Management	++	++	++	+	+	+	++	+
Agronomic measures: Conservation Agriculture	++	++	++	++	++	++	++	++
Agro-forestry	+++	++	+++	++	++	+++	+++	++
Sustainable planted forestry	+++	+	++	++	++	++	++	++
Sustainable forest management in drylands	+++	++	+++	+++	++	+++	+++	++
Rainwater harvesting	++	+++	+++	+	++	+	+++	+
Cross-slope barriers	++	++	+	+	+	++	++	+
Integrated crop-livestock management	++	++	++	+	+	+	++	++
Rangeland management	++	+++	++	++	+++	++	++	++

Source: Liniger et al., 2011.

Table A2. Short and long-term benefit cost ratios for selected SLWM measures

Measure	Short-term benefit cost	Long-term benefit cost
Agronomic measures		
Improved vegetation and soil cover	+(+)	+++
Soil surface and sub-surface treatment	+(+)	+++
Integrated soil fertility management	++	+++
Integrated pest management	NA	NA
Improved crops and varieties	NA	NA
Agro-forestry and sustainable forest management		
Agroforestry	+	++
Sustainable planted forestry	-	++
Community-based forestry management	-	++
Rainwater harvesting		
In-situ techniques to promote infiltration	NA	NA
Micro-catchments	+ / ++	++
Macro-catchments	--	++ / +++
Roof-top rainwater harvesting	--	+++
Integrated watershed management		
Overall	NA	NA
Cross-slope barriers		
Contour bunds	-	++
Vegetative strips	+ / -	++
Trenches	NA	NA
Radical or bench terraces	--	++
Integrated crop-livestock management and rangeland management		
Overall	NA	NA
Aquatic weed control		
Overall	NA	NA
Fisheries management		
Overall	NA	NA
Innovative financing and support for livelihoods		
Overall	NA	NA
Institutional and capacity development at district and community levels		
Overall	NA	NA

Source: Liniger et al. (2011).

Appendix 3 Detailed list of environmental and natural resource management measures identified in LVB

This appendix details the full list of measures assessed in Chapter 6.

Transboundary cooperation, institutional strengthening, information sharing, and knowledge management

Planning, strategy, and financing

- Revise and develop a regional Climate Change Adaptation and Mitigation Strategy and Action Plan to succeed the existing Plan for the period 2018 to 2023;
- Develop a regional investment plan for wastewater and sanitation, improved water quality and ecosystem services;
- Develop a strategy for resource mobilization, the tracking of finance for climate action and ENRM.

Policies, regulations, and guidelines

- Finalize the New Water Release and Abstraction Policy for Lake Victoria Basin;
- Develop climate-resilient catchment management plans—these could be combined with the development of Transboundary Water Resource User Associations (TWRUAs);
- Develop guidelines and best practices for integrating climate resilient design practices into infrastructure planning;
- Strengthen the implementation and enforcement of regional policies on good fisheries practices.

Research, monitoring, and knowledge management

- Strengthen and enhance the monitoring and collection of data—investments in hardware (water quality stations, automatic weather stations, use of the novel techniques such as Unmanned Autonomous Vehicles), software, and human resources to undertake monitoring and data collection activities. Monitoring could extend to atmospheric deposition;
- Strengthen and enhance the management and sharing of data and knowledge—establish a regional hub for data, information, and knowledge-sharing around climate change in the LVB. Inter-sectoral information platforms and data sharing frameworks on water quality, ecosystem health, biodiversity, fish stocks and catches and aquatic weeds. Further develop the Water Resources Information System that integrates climate change and Integrated Water Resources Management;
- Support research and assessments of existing and emerging environmental and climate issues. This work could include research on the source and fate of pollutants, including emerging ones. Research investments could also strengthen the knowledge base for technological innovation in areas that include resource efficiency and cleaner production. Research could be shared through the preparation of a periodically produced State of the Lake Report;
- Development and strengthening of Early Warning Systems and support of the relevant actors taking action to support Disaster Risk Management (DRM).

Institutional and capacity development

- Participate in the development of sustainable funding mechanisms for regional bodies such as the LVBC. e.g. partnerships, Lake Victoria Basin Environmental Trust Fund, to increase the institutional and financial sustainability of the LVBC;
- Strengthen partnerships between LVBC and other institutions within the Basin including other EAC institutions, such as the Nile Basin Initiative, ICPAC, and RCMRD;
- Strengthened technical knowledge within the LVBC secretariat and their relevant partners;
- Support basin-wide knowledge transfer through dissemination of best practices in the agriculture, fisheries, and industrial sectors.

Addressing non-point source pollution through SLWM practices

Agronomic measures, including conservation agriculture and integrated soil fertility management

- Improved vegetation and soil cover—including improved soil cover through the selection of species or increased plant density, cover cropping, earlier planting, relay planting, mixed or intercropping, contour planting, and mulching (adding or leaving vegetative/non vegetative material on the surface to retain soil moisture and structure), and applying trashlines (organic waste after harvesting);
- Soil surface and sub-surface treatment—including conservation tillage (zero or minimum tillage with reduced topsoil disturbance), contour tillage/ridging, breaking compacted topsoil through e.g. ripping, ploughing, harrowing, hoeing, pit construction, breaking compacted subsoil/hardpans, deep ripping /sub soiling;
- Integrated soil fertility management—application of inorganic (mineral) and organic fertilizers, intercropping of cereals and legumes for biological nitrogen fixation, manuring/composting of soils, applying soil conditioners, and crop rotations and fallow periods;
- Integrated Pest Management—including the use of minimal pesticides, focusing on acceptable pest levels (control rather than elimination), and using biological and mechanical techniques for pest control.

Sustainable forest management, agro-forestry, and silvo-pastoralism

- Support for agroforestry programs, including silvo-pastoralism;
- Tree planting and restoration of forests—promote afforestation and reforestation with special attention to indigenous species and practices;
- Reduce deforestation by providing alternative clean energy sources and efficient appliances for energy use, management, and conservation.

Rainwater harvesting

- In-situ techniques that aim to maximize the infiltration and storage of water within the soil;
- Micro-catchments that include small holes and pits to collect and store rainwater;
- Macro-catchments that include channels and structures on a larger scale—these can also include small ponds and charco dams, roadside runoff management and storage, and troughs for cattle and water pans. This also includes cut-off drains and waterways, and

diversion channels, and the establishment of small-scale irrigation schemes, and individual farmer irrigation systems;

- Roof-top rainwater harvesting schemes with storage tanks. These systems can be attached to houses or larger communal structures such as schools and health centers.

Integrated watershed management

- Wetland protection, or (re)construction and rehabilitation of wetlands;
- Gully protection and rehabilitation / river bank protection and riparian vegetation;
- Protection of water sources (ground and surface water);
- Promotion of environmental flows.

Cross-slope barriers

This category is primarily a structural measure which aims to reduce soil loss and the retention of soil moisture through the construction of terraces and other barriers.

- Contour bunds (stone and earth bunds) and progressive terraces;
- Vegetative strips;
- Trenches;
- Terracing—radical or bench terracing.

Integrated crop-livestock management and rangeland management

- Grazing control (fencing), grazing zoning, and rotational grazing;
- Reseeding and rehabilitation of grasslands;
- Support for livestock management (e.g. fodder supplies, improved breeds, water supplies);
- Support for dispute resolution mechanisms.

Aquatic weed control

- Implement water hyacinth control (through physical, biological, and chemical removal);
- Promote private sector and community participation in weed control through incentives and training, as well as support business cases for economic utilization e.g. biofuel;
- Establish and support water hyacinth coordination unit for sustainable options for water hyacinth control, including training for technical staff.

Fisheries management

- Construction of climate-resilient infrastructure (jetties, storage and processing facilities);
- Improved enforcement of regulations on catches and gear;
- Support for improved fishing gear (e.g. nets which support legal catches);
- Enhancement and expansion of protected fishing zones;
- Support for innovative aquaculture fishing techniques such as aquaponics and culture-based fisheries, and low-cost fisheries aggregation devices (FAD);
- Training and support for best management practices in the fisheries sector.
- Protecting and restoring wetlands as breeding grounds for fish

Innovative financing and support for livelihoods

- Payment for ecosystem services to disincentivize environmentally degrading activities and incentivize environmentally sustainable activities;
- Support for markets, value chains, and cooperatives, including post-harvest technologies;
- Support for income diversification in areas such as fisheries and agriculture to reduce reliance on single income sources.

Institutional and capacity development at district and community levels

- Capacity building and training of technical and district staff in SLWM techniques;
- Community capacity building in SLWM techniques. Promoting farmer-to-farmer learning, demonstrating successful experiences: adopting good practices and sustainability for watershed interventions across the basin; targeted female participation in leadership, decision-making, planning and implementation and equitable sharing of benefits of SLWM;
- Financial and material support (incentives and subsidies) to communities to support SLWM;
- Monitoring, assessment and research of technologies and impacts;
- Participatory Land Use Planning (all sectors), and participatory catchment planning and implementation.

Addressing point source pollution produced by industrial and municipal waste

Point source pollution from municipal and industrial sources has been identified as a major problem that diminishes water quality in Lake Victoria. This category includes investments that address the design and construction of improved infrastructure, particularly in the sanitation and solid waste management sector. It also includes support for improved industrial processes. This support can come in the form of training, financial support to adopt improved processes, and the enforcement of regulations to stop environmentally damaging processes. Some of the measures in this sector can be strongly linked to climate mitigation through increased resource efficiency. The major focus of climate adaptation is ensuring that point sources of pollution are not increased during climate shocks. For example, integrating the principles of climate resilient design into infrastructure development should reduce the risk of climate-induced pollution incidents. Lastly, there is a significant focus on the improved monitoring of discharges and resulting water quality, both at the local or national scale, and by supporting joint regional monitoring efforts. The following measures are considered:

Infrastructure for sanitation and waste management

- Develop and implement sanitation master and pollution prevention plans with a focus on climate change and extreme weather events. Include vulnerability assessments of existing infrastructure;
- Feasibility studies, design, and construction of infrastructure for municipal water and stormwater management, incorporating principles of climate resilient design. Infrastructure to include ‘gray’ infrastructure, such as wastewater treatment plants and drainage, and ‘green’ infrastructure, to include green roofs, bioretention areas, open spaces and constructed wetlands;
- River improvement schemes that contribute to reduced flood risk and discharge of pollutants;

- Improved collection and disposal services for solid waste. Investments in new or improved landfill sites - including improved protection and practices, including climate-resilient on-site disposal of effluent.

Improved industrial waste management

- Technical advisories to support RECP with a focus on climate adaptation and mitigation;
- Promote cleaner technologies with, *inter alia*, financial support and grants.

Regulations, policies, and guidelines for municipal and industrial waste management

- Enforce laws on urban planning and storm water management in urban areas;
- Strengthen regulatory and incentive systems for environmental pollution control and prevention;
- Promote Environmental Impact Assessments for new infrastructure and industrial investments.

Research, monitoring, and knowledge management

- Water quality monitoring and discharge assessments—this would support municipal and national level efforts to collect data on water quality in the Lake and in major tributaries, using innovative technologies where possible;
- Support national level efforts to share data on water quality and quantity in the Lake and in major tributaries regionally (e.g. through a Water Resources Information System);
- Conduct research to link regional water quality monitoring with climate observations to underpin knowledge of climate impacts on water quality. Assess sources of industrial and municipality effluent loading (including sources, composition and quantities), seasonally and during climate extremes.

Capacity and institutional strengthening for municipalities and enforcement agencies

- Institutional strengthening for enforcement agencies, including advanced training for adherence at local and national levels and beyond;
- Enhance capacity of institutions and bodies responsible for water and sanitation on climate change impacts and the water sector. Provide technical support to develop pollution prevention strategies and policies, with a focus on climate change and extreme events;
- Raise awareness on Regional Industrial and Municipal Effluent discharge into the river system and the Lake, particularly during extreme events, and the risk to public health.

Appendix 4 Results of assessing resilience attributes supported by investments

Table A3. Transboundary cooperation, institutional strengthening, information sharing, and knowledge management

Option	Robustness	Learning	Flexibility	Self-organization	Inclusion
Planning, strategy, and financing					
Revise and develop a regional Climate Change Adaptation and Mitigation Strategy and Action Plan to supersede the existing Plan for the timeframe 2018-2023.		✓	✓	✓	
Develop a regional investment plan for wastewater and sanitation, improved water quality and ecosystem services.		✓	✓	✓	
Develop a strategy for resource mobilization, and the tracking of finances.		✓	✓	✓	
Policies, regulations, and guidelines					
Finalize the New Water Release and Abstraction Policy for the Lake Victoria Basin.		✓	✓	✓	
Develop climate-resilient catchment management plans. This could be combined with the development of Transboundary Water Resource User Associations (TWRUAs).	✓	✓	✓	✓	✓
Develop guidelines and best practices for integrating climate resilient design practices into infrastructure planning.	✓	✓	✓		
Strengthen implementation and enforcement of regional policies on good fisheries practices.	✓	✓	✓	✓	
Research, monitoring, and knowledge management					
Strengthen and enhance environmental monitoring and the collection of data		✓		✓	
Strengthen and enhance the management and sharing of data and knowledge.		✓		✓	✓
Support research and assessments of existing and emerging environmental and climate issues.		✓		✓	
Develop and strengthen Early Warning Systems and DRM.		✓	✓	✓	✓
Institutional and capacity development					
Participate in the development of sustainable funding mechanisms for regional bodies.		✓		✓	

Strengthen partnerships between LVBC and other institutions within the Basin, including technical capacity development.		✓	✓	✓	
Build capacity for research and monitoring of environmental and climate conditions.	✓	✓	✓	✓	
Support basin-wide knowledge transfer through dissemination of best practices.	✓	✓	✓	✓	✓

Table A4. Addressing non-point source pollution through SLWM practices

Option	Robustness	Learning	Flexibility	Self-organization	Inclusion
Agronomic measures	✓		✓		✓
Sustainable forest management, agro-forestry, and silvo-pastoralism	✓	✓	✓		✓
Rainwater harvesting	✓		✓		✓
Integrated watershed management	✓	✓	✓	✓	✓
Cross-slope barriers	✓				✓
Integrated crop-livestock management and rangeland management	✓	✓	✓	✓	✓
Aquatic weed control	✓				✓
Fisheries management	✓	✓	✓	✓	✓
Financing and improved livelihoods	✓	✓	✓	✓	✓
Institutional and capacity development	✓	✓	✓	✓	✓

Table A5. Addressing point source pollution produced by industrial and municipal waste

Option	Robustness	Learning	Flexibility	Self-organization	Inclusion
Infrastructure for sanitation and waste management					
Develop and implement sanitation master and pollution prevention plans with a focus on climate change and extreme weather events.	✓	✓	✓	✓	

Feasibility studies, design and construction of infrastructure for municipal water and stormwater management, incorporating principles of climate resilient design.	✓		✓	✓	
River improvement schemes that contribute to reduced flood risk and discharge of pollutants.	✓			✓	✓
Improved collection and disposal services for solid waste.	✓			✓	✓
Improved industrial waste management					
Technical advisories to support RECP with a focus on adaptation and mitigation.	✓	✓			✓
Promoting cleaner technologies through financial support, including grants.	✓	✓	✓		
Regulations, policies, and guidelines for municipal and industrial waste management					
Enforce laws on urban planning and storm water management in urban areas.	✓	✓		✓	
Strengthen regulatory and incentive systems for environmental pollution control and prevention.	✓			✓	✓
Promote Environmental Impact Assessments for new infrastructure and industrial investments.	✓	✓		✓	
Research, monitoring, and knowledge management					
Water quality monitoring and discharge assessments.		✓		✓	
Support national level efforts to share data on water quality and quantity nationally and regionally.		✓		✓	✓
Conduct research to link regional water quality monitoring with climate observations to underpin knowledge of climate impacts on water quality.		✓		✓	✓
Capacity and institutional strengthening for municipalities and enforcement agencies					
Institutional strengthening for enforcement agencies.	✓	✓		✓	
Enhance capacity of institutions and bodies responsible for water and sanitation on climate change impacts and the water sector.	✓	✓		✓	
Raise awareness on regional industrial and municipal effluent discharge into the river system and the Lake.	✓	✓		✓	✓