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TECHNICAL REPORT

VULNERABILITY AND ADAPTATION IN THE MARA RIVER BASIN

May 2019

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Cover Photo: Tea plantation near Bomet, Kenya; photo by Fernanda Zermoglio, 2018

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Adaptation Thought Leadership and Assessments (ATLAS)

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ACRONYMS

ATLAS	Adaptation Thought Leadership and Assessments
CFA	Community Forest Association
CRU	Climate Research Unit
ENSO	El Niño Southern Oscillation
GCM	Global Climate Model
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
MRB	Mara River Basin
RCP	Representative Concentration Pathway
SCMP	Sub-Catchment Management Plan
USAID	United States Agency for International Development
WAP	Water Allocation Plan
WRMA	Water Resources Management Act
WRUA	Water Resources User Association

EXECUTIVE SUMMARY

OVERVIEW

The fate of the Mara River Basin's (MRB) inhabitants, and the ecosystems on which they rely, will depend on the interplay of population pressure, economic development, urbanization, land use changes (including deforestation and land degradation) and changes in water quantity and quality. Each is linked to the others, which poses complex problems for managing land and water resources. As populations grow or move to cities, their demand for water resources changes. Climate variability and change will multiply these pressures on water resources.

The main objective of this assessment is to evaluate the vulnerability of the MRB to climate variability and change and provide investment recommendations for donors, the government and the private sector to address the changing nature of risk across the basin.

CLIMATE RISKS AND WATER AVAILABILITY

Weather and climatic conditions in the MRB are a product of both human-induced climate change and natural cyclical climate patterns. The climate of the basin is changing; temperatures have risen by 1°C–1.5°C and rainfall is becoming more erratic. This is projected to continue to change, as outlined below.

Increasing temperatures and intensity and duration of heat waves. Compared with 1985–2015, the average temperature of the MRB is expected to increase by 0.7°C–1.97°C by 2030 and 1.5°C–2.71°C by 2050, with the most warming during the months of the long rains (March to May). The basin is also expected to see an increase in the duration of heat waves in Kenya (+9 to 30 days) and in Tanzania (+7 to 22 days). Increases in temperature and in the duration of heat waves can impact human populations, agriculture and livestock and ecosystems. A complete list of potential climate risks is provided in the report, with some examples noted here:

- Loss of crops or decreased yields caused by decreased soil moisture and infiltration rates.
- Increased poverty and food insecurity caused by loss of crops or decreased yields, loss of livestock, or loss of other sources of food and income.
- Declining wildlife populations due to heat stress and reduced water availability from increased evaporation, leading to both a loss of biodiversity and decreased revenue from tourism.

Continued increase in the frequency and intensity of rainfall and drought events. Extreme rainfall and drought events have impacted the basin's economy, environment, and people. For example, the 1997–98 El Niño event led to widespread flooding throughout the East Africa region and caused major changes in the course of the Mara River. These events can have long-lasting impacts, such as:

- Increased poverty and food insecurity caused by loss of crops or decreased yields, loss of livestock or loss of other sources of food and income.
- Decreased water quality due to sedimentation from river bank erosion and deforestation, or excessive water abstractions.
- Water shortages caused by drought or poor planning and management of water resources, particularly within populations that rely primarily on surface water.

Increased interseasonal rainfall variability. The length of time that soil temperature and soil moisture conditions are suitable for cash and subsistence crops is changing, with delayed starts and more frequent failure of the short rains, making for less-reliable growing seasons. This increased unreliability can have major impacts; for example:

- Increased poverty and food insecurity caused by loss of crops or decreased yields, loss of livestock or loss of other sources of food and income.
- Reduced access to drinking water due to drying up of small streams and seasonal water decreases.
- Changes in the suitability of certain crops, requiring either altered planting and harvesting schedules or outright substitution for a more suitable crop.

WHAT MAKES THE BASIN'S INHABITANTS VULNERABLE?

Sustained population growth and increasing urbanization. Population growth rates throughout the basin have averaged 3–4 percent annually for at least the past decade and appear to be poised to continue at a similar rate. This rapid and often unplanned growth has led to land conversion as well as increased urbanization, which in turn has increased the demand for water, food, energy and infrastructure development.

Land use change. As a result of population growth and development, significant tracts of forest and grassland have been converted for agriculture, livestock grazing, and human settlements. The loss of forest has led to soil erosion and high sediment loads, impacting water availability and quality in the Mara River, as well as groundwater infiltration. The expansion of grazing land has similarly led to increased erosion and pollution.

High levels of poverty and food insecurity. High poverty rates[1] are continual and pervasive throughout the basin, ranging from a high of 48.8 percent (Bomet) to a low of 22.6 percent (Narok). Poverty rates have been trending downward, however, with rates being reduced from 6 percentage points (Mara region) to almost 20 percentage points (Nakuru) over the past decade. Food insecurity remains a significant issue as well and is particularly pronounced between January and April in Bomet and the Mara wetlands, when harvested subsistence crop stocks are typically depleted.

Dependence on rainfall for agriculture. The vast majority of crops (as high as 98 percent in some areas) in the MRB are rainfed, making farmers in the area completely dependent on traditional rainy seasons and vulnerable to any changes in rainfall patterns.

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[1] Poverty rates noted are from 2016 and defined as those living below the international poverty line (US$1.90 per day in 2011 PPP)

Dependence on unimproved water sources for drinking water. Domestic water in the MRB is largely drawn from unreliable, unprotected sources, with approximately 70 percent of the population using unprotected springs, surface water and shallow wells as their primary source of drinking water.

Insufficient water resource planning, management and enforcement. Efforts to manage transboundary water resources between Kenya and Tanzania have been relatively uncoordinated. Institutions that manage water resources and enforce laws and regulations often have inadequate technical and financial capacity.

METHODS

This climate change vulnerability assessment for the MRB aims to shed light on the pressures that face the MRB and to offer insights on priority vulnerabilities of the MRB as a whole. This information provides the evidence base to support climate resilient investments across the basin, many of which also reflect those highlighted by key stakeholders in the Nyangores sub-catchment and the Mara Wetlands (see case studies in Annexes A and B).

Vulnerability is a function of exposure, sensitivity and adaptive capacity, where:

- *Exposure* is a function of location and represents the direct and indirect risk posed by weather- and climate-related hazards and other pressures such as population growth, land use and land cover changes.
- *Sensitivity* is the propensity to be adversely affected by weather and climate-related hazards.
- *Adaptive capacity* is a function of the tools and resources available for stakeholders to respond to current stresses and prepare for future stresses.

The assessment addresses these components of vulnerability in part through a spatial analysis of key factors driving these changes and in part through an institutional analysis that evaluates the extent to which institutions are prepared to address the current and emerging risks. It aims to answer several critical questions:

- To what climate risks are basin users vulnerable? How will this vulnerability change under a changing climate? (exposure)
- What sectors/livelihoods of the basin are vulnerable and why? (sensitivity)
- What resources are available to cope with and confront current and future risks? (adaptive capacity)

RECOMMENDATIONS TO ADDRESS THE RISKS AND IMPACTS OF CLIMATE CHANGE IN THE MARA RIVER BASIN

Reducing and addressing the basin's risks to climate change will require updating current policies and programs and implementing new activities to explicitly consider and address climate variability and change. Adaptation actions should focus on building the climate resilience[2] of the basin's population and their livelihoods, reducing overall vulnerability[3] and developing the capacity of stakeholders to address the risks noted in this report. Entry points include: 1) strengthening governance and institutions, 2) improving the quality and use of available information for decision-making and 3) piloting or scaling-up interventions to address risks and reduce pressures, including engagement with the private sector to improve community resilience. These are structured below to reflect the varying conditions of the basin's regions, risks and priorities as described in the report.

STRENGTHENING GOVERNANCE AND INSTITUTIONS

Upper basin

- Develop costing concept note for stream restoration, including engineering designs and the participatory process of community engagement in the work.
- Revise sub-catchment management plan (SCMP) priorities to reflect experiences to date on effective adaptation strategies for livelihood needs and climate risks.
- Strengthen WRUAs' ability to promote climate-resilient practices through awareness-building campaigns and by adding revenue streams to undertake additional monitoring and pilot projects.

Lower basin

- Increase membership in water resources user associations (WRUAs) through awareness-building campaigns, and by adding revenue streams to undertake additional monitoring and pilot interventions.
- In the water allocation plans (WAPs) for Kenya and Tanzania, address improving water management to counter reduced water flows to catchment areas.

IMPROVING INFORMATION

Upper basin

- Work with the local meteorological office to define key variables affecting farmers and develop a method for disseminating this information to members of the local WRUA and Community Forest Association (CFA) by radio and/or SMS.
- Work with the Famine Early Warning Systems Network (FEWS NET) to ensure that beneficiaries are able to access this information easily in a format they can understand and act on to make better decisions.
- Develop case studies on alternative livelihood strategies highlighted by community members, including improved production of milk goat, avocado, tree tomato, and passion fruit.

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[2] Climate resilience – USAID defines resilience as "the ability of people, households, communities, countries and systems (social, economic, ecological) to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth" (USAID 2012a).

[3] Reducing vulnerability – implies actions that aim to reduce the shocks and stresses to climate risks, but these do not necessarily build resilience to a changing risk profile.

Lower basin

- Improve data availability for the Mara Wetlands and adjacent areas, including regular biodiversity, social and demographic, and water level, quality and quantity surveys.
- Develop training and awareness materials, and hold trainings and community meetings to enhance communication and capacity among MRB stakeholders to support proper conservation and management of the wetland as a transboundary resource.
- Repair existing hydro-meteorological data stations, reinstitute regular data collection, and increase number of data stations.

PILOTING INTERVENTIONS

Upper basin

- Invest in technical assistance to members of the CFA to safeguard investments and improve the viability of the production of new crops such as avocado, tree tomato, and passion fruit.
- Develop case studies on alternative livelihood strategies highlighted by community members, including improved production of milk goat, avocado, tree tomato, and passion fruit.
- Improve access to credit, insurance and markets so that beneficiaries have options and safety nets in case of climate-related events.
- Continue to promote oil and water conservation techniques, such as mulching and planting cover crops to reduce sediment loads.
- Continue to invest in stream restoration and sediment management based on a prioritized list of those at risk from the revised Sub-Catchment Management Plan (SCMP).

Lower basin

- Invest in veterinary and crop extension services to address the increased risk to crops and livestock from diseases.
- Pilot small-scale irrigation schemes that could safeguard crop and livestock productivity during dry periods.
- Introduce or scale up interventions to increase forest coverage and reduce deforestation by providing inputs (e.g., seedlings/saplings, soil amendments), equipment, training and extension services to enable on-farm agroforestry, and encourage use of improved cookstoves and alternative fuels, such as biogas which is currently being used in the Nyangores basin.

INTRODUCTION

The Mara River Basin (MRB) is home to more than 1.28 million people in Kenya and Tanzania and supports a number of critically important wildlife areas. However, pressures such as population growth and land use change threaten water resources, and the threat to water resources in turn threatens development of key economic sectors such as agriculture, tourism and biodiversity. These pressures are likely to be intensified by climate variability and change.

Key pressures in the basin include:

- *Sustained population growth and increasing urbanization:* Population growth rates throughout the basin have averaged 3–4 percent annually for at least the past decade and appear to be poised to continue at a similar rate. This rapid and often unplanned growth has led to land conversion as well as increased urbanization, which in turn has increased the demand for water, food, energy and infrastructure development.
- *Land use change:* As a result of population growth and development, forest and grassland have been converted for agriculture, livestock grazing and human settlements. The loss of forest has altered micro-climates in the basin, and led to soil erosion and high sediment loads, impacting the availability and quality of water in the Mara River, as well as groundwater infiltration. The expansion of grazing land has similarly led to increased erosion and pollution and has expanded into wildlife corridors, leading to conflicts between people and wildlife.
- *Insufficient water resources planning, management, and enforcement:* Efforts to manage transboundary water resources have been relatively uncoordinated. Institutions that manage water resources and enforce laws and regulations often have inadequate technical and financial capacity.
- *Effects of climate change:* The effects of climate change and variability are already being felt in the area with an increase in the frequency of droughts and floods and changes to crop calendars and suitability. Projections indicate that temperatures will continue to increase, extreme events (e.g., droughts, floods, heat waves) will become more frequent and intense, and seasonal rainfall patterns will shift.

Key risks in the basin include:

- Loss of crops and livestock from the increased frequency and intensity of floods and droughts due to climate variability and land use change.
- Increased poverty and food insecurity caused by loss of crops, livestock and other sources of food and income.
- Water shortages caused by drought or poor planning and management of water resources, particularly for populations that rely primarily on surface water.
- Decreased water quality due to sedimentation from river bank erosion and deforestation, excessive water abstractions and increased use of agro-chemicals for pest and disease control in crops and livestock.
- Declining wildlife populations due to resource competition and encroachment into habitats, leading to both a loss of biodiversity and decreased revenue from tourism.
- Destruction of housing and other infrastructure caused by flooding, as well as more minor damage caused by extreme precipitation and rising temperatures.

OBJECTIVES OF THIS ASSESSMENT

The main objectives of this assessment are to evaluate the vulnerability of the MRB to climate variability and change and provide investment recommendations for donors, the government and the private sector to address risks. The report is structured as follows:

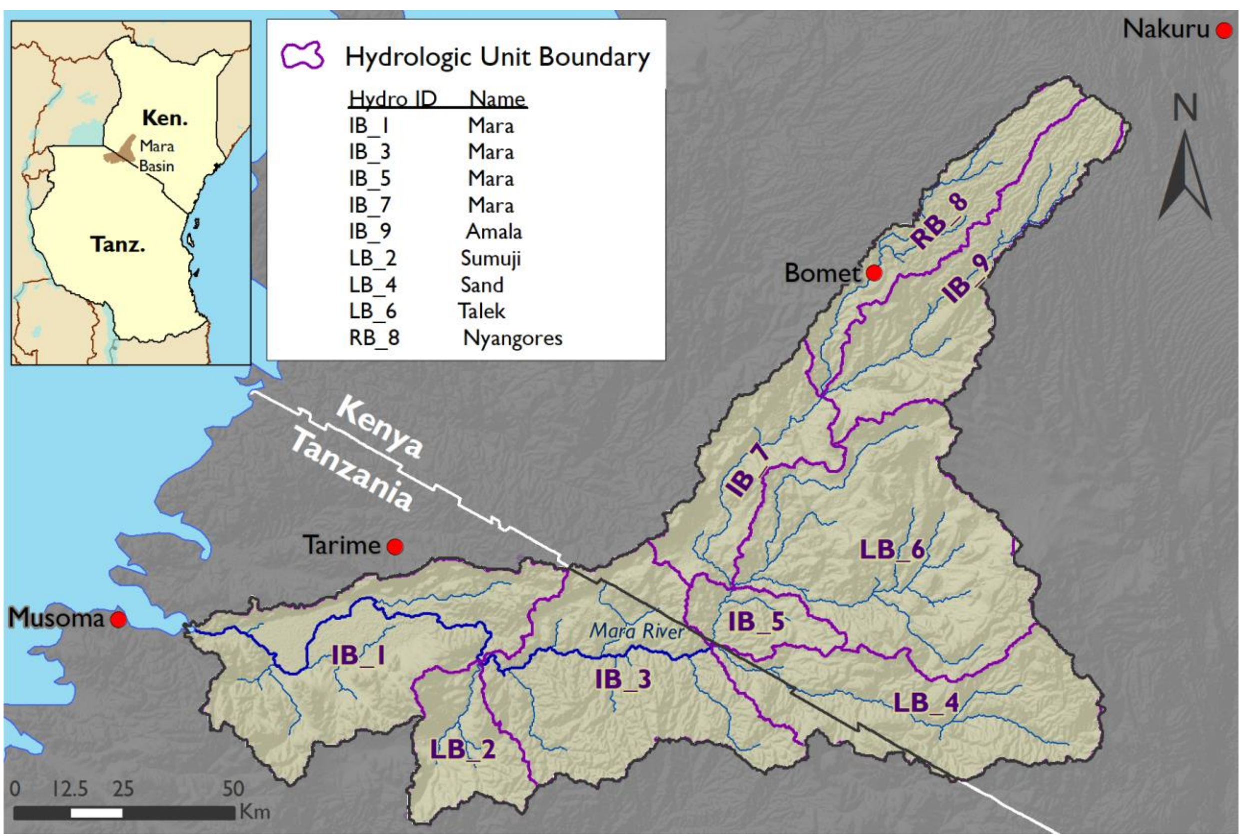
- Section 1 offers an overview of the basin as well as a summary of the current context and trends in the basin, and an outline of the institutional structure governing water resources.
- Section 2 provides an assessment of the basin's vulnerability to climate variability and change, including the methodological approach, an overview of historical climate trends, updated climate projections, and a summary of the changing nature of risk across the basin, both from climate and other pressures.
- Section 3 offers recommendations to reduce risk.

OVERVIEW OF THE MARA RIVER BASIN

The MRB is shared between Kenya and Tanzania and covers Bomet, Narok and Nakuru counties in Kenya, and Tarime, Rorya, Serengeti and Butiama districts in Tanzania (Figure 1). The MRB has a catchment area of approximately 13,750 km^2, with an upper basin area of about 8,940 km^2 (65 percent) in Kenya and a lower basin area of about 4,810 km^2 (35 percent) in Tanzania (WREM International 2008).

The source of the Mara River is the Enapuyiapui Swamp in the Mau forest complex, where two permanent tributaries—the Amala and Nyangores—flow through the Mau forest and converge at the base of the Mau escarpment to form the Mara River. As the river flows through the rangelands and the Maasai Mara and Serengeti parks, it is joined by the Engare Ngobit, Talek and Sand rivers, and as it crosses the border with Tanzania, it is joined by the Tobora B, Somoche and Tigithe tributaries before entering the Mara Wetlands and eventually draining into Lake Victoria (Melesse et al. 2008).

Figure 1: The Mara River Basin



Projecting from the most recent figures for Kenya (2009) and Tanzania (2012), an estimated 1.28 million people live in the MRB, with approximately 861,000 people in the Kenya sub-basin and 419,000 people in the Tanzanian sub-basin (KNBS 2009, URT 2012). The residents of the MRB rely primarily on agriculture and livestock production for income, and also forest products, mining, and wildlife and tourism. The MRB is also home to two key wildlife preserves—Serengeti National Park and Maasai Mara National Reserve—as well as two important wetlands: the Enapuyiapui Swamp in Kenya and the Mara Wetlands in Tanzania.

BIOGEOGRAPHIC CHARACTERISTICS AND TRENDS

The MRB can generally be divided into three zones: the highland area of the Mau forest in Kenya, the mid-elevation rangelands that extend to both Kenya and Tanzania (collectively the upper basin) and the lower elevation wetlands in Tanzania where the Mara River enters Lake Victoria (lower basin).

The highland area in Kenya is at an elevation of 1,700–2,200 m, and land use consists primarily of closed forest, tea plantations and small-scale agriculture. The Mau forest complex is the largest closed canopy forest in East Africa; however, forest cover decreased in the MRB from 20 percent to approximately 7 percent between 1976 and 2014, and the majority of this is attributed to deforestation in the Mau forest complex. This deforestation is largely a result of agricultural expansion, primarily taking place through the conversion of forest lands to small-scale farming: small-scale agriculture increased from approximately 6.5 percent of the landscape to 21 percent in the same period.

The rangelands lie at an elevation of 1,400–1,700m, and land use consists of commercial large-scale farming, small-scale subsistence farming, pastoral communal grazing areas and mining areas. The Maasai Mara National Reserve consists mostly of grasslands with a cover of shrubs and thorny bushes increasing in the northern and eastern edges of the reserve, and Serengeti National Park is primarily savanna with a mixture of grasses, shrubs and trees (Bartzke et al. 2018).The rangelands are classified as semiarid, and thus roughly half of the land is nonarable. Commercial monoculture farming on the Kenyan side has increased in recent years, and as a result, grass and shrubland areas decreased by 12 percent (537 km^2) between 1986 and 2015 (Lake Victoria Basin Commission [LVBC] 2016).

The wetlands in Tanzania lie at an elevation of 1,100–1,300 m, and land use consists of the wetland system itself (floodplain grassland, woodland, swamp and open water), surrounded by mixed woodland and shrubland which is interspersed with crops and pasture. Much like on the Kenya side of the border, population growth has been rapid, increasing by 28 percent between the 2002 and 2012 census. This has led to the conversion of forest and wetlands to crop and pasture lands; by current estimates, more than 100 km^2 of the wetlands have been converted to agriculture. Meanwhile, sediment deposition at the river's edge due to upstream activities has more than doubled the wetland extent over the past 30 years by pushing backflow towards the wetlands. The wetlands have a total area ranging from 390 km^2 to more than 500 km^2, depending on seasonal flooding (Ministry of Natural Resources and Tourism 2017).

SOCIOECONOMIC CHARACTERISTICS AND TRENDS

As noted above, the estimated total population (2018) of the MRB is 1.28 million. Estimates for the annual population growth rate of the MRB vary from 3–4 percent based on source and geographic location within the basin. Growing at 3–4 percent per year, the population of the basin will likely be nearly 1.5 million by 2020, and perhaps as high as 2 million by 2030. As a result of the rapidly increasing population, analysis of Landsat data showed that agriculture increased from 4.6 percent to 13.0 percent of the total land use (an increase of 110,000 hectares), and human settlements and infrastructure increased by 5,300 hectares between 1995 and 2015 (LVBC 2016).

Population densities are highest in the highlands in Kenya, and the lowland area in Tanzania, where land is more fertile. For example, population densities along the forest margins in Kenya are well above the country average, with over 300 people per square kilometer. The rangelands have a much lower population density due to its semiarid nature and the two large nature reserves (LVBC 2016). For example, the population density in Serengeti district in Tanzania is just over 22 people per square kilometer.

Poverty—defined as those living below the international poverty line (US$1.90 per day in 2011 PPP)—is pervasive throughout the basin but rates have been trending downward. In the 2015/16 Kenya Integrated Household Budget Survey, the estimated poverty rate in Bomet was 48.8 percent, in Nakuru, 29.1 percent and in Narok, 22.6 percent. While poverty rates remain high, they are markedly lower than in the 2005/2006 survey: Bomet, 58.7 percent; Nakuru, 50.1 percent and Narok, 26.7 percent. In the most recent 2011/12 Household Budget Survey in Tanzania (which does not disaggregate to the district level), poverty levels in the Mara region were estimated at 26.2 percent, nearly 24 percentage points lower than the estimate of 50 percent in the 2000/2001 survey. However, given the highly rural nature of the population in the MRB in Tanzania, it is likely that poverty levels in the basin are higher than the overall regional average.

Subsistence agriculture and livestock production are the dominant economic activities in the MRB, with more than 60 percent of households engaging in smallholder subsistence farming as their primary occupation, followed by tourism and cash crop production. Other economic sectors in the basin include mining, energy, service industry, trade and industry, and forestry, each of which is overseen by a respective ministry.

The highland area of the basin in Kenya is dominated by small-scale tea farmers, coupled with subsistence farming of crops including maize, potatoes, beans, kales, and millet. Though tea production continues to dominate economic activities in the highlands, as the price of tea has fallen and production costs have increased, some farmers are now diversifying (plots are typically 2–2.5 acres) to produce passion fruit, tree tomatoes, and avocados.

In the lower highlands and rangelands, livestock and milk production (primarily beef and dairy cattle, goats, and sheep) dominate as sources of income, along with irrigated large-scale commercial agricultural operations. Subsistence crops grown in this area include sweet potatoes, maize, onions, beans, sorghum, and millet. In and around the Masai Mara and Serengeti parks, tourism is the main economic activity, benefiting primarily those employed in the industry by large international lodge owners and some district governments operating lodges and/or parks, along with small- and medium-scale livestock rearing conducted by pastoral herdsman.

On the Tanzanian side of the MRB around the wetlands, small-scale subsistence farming and livestock production dominate, supplemented by cash crops, fishing and small-scale mining (with the exception of one large gold mine, Mara North). Crops and livestock are even more important in this area, with 83 percent of households engaging in agriculture as their primary occupation. More than 50 percent of households grow maize, which is intercropped with cotton as well as traditional crops more resilient to drier conditions such as cassava, sorghum, beans, sweet potatoes, millet, and oilseeds. Sixty-two percent of households keep livestock, primarily cattle, goats, sheep, and chickens.

The trend indicates that crops and livestock continue to be the dominant economic activities in the MRB, although there has been some shift in crops (e.g., tea) and intensification of agriculture (i.e. those using the surface water from the Mara river directly for irrigated commercial crops, which is currently limited to a small number of farms in Kenya and large-scale livestock operations, though if future plans for irrigated development are carried out, this could potentially be unsustainable). Tourism also continues to be a growth sector, as yearly visitors to Maasai Mara and Serengeti have increased over the past decade, but with limited economic benefits to the basin inhabitants.

WATER RESOURCES

The primary use of the Mara River is for domestic water, and surface water is important for agriculture, livestock, wildlife, tourism, and industry. The demand for water has increased over the past 30 years because of increases in population, area under cultivation, livestock, and tourism.

Domestic water in the MRB is largely drawn from unprotected sources. On the Kenyan side, approximately 50 percent of residents collect water directly from the Mara River or its tributaries, and another 20 percent get water from unprotected wells and springs (Metobwa et al. 2018). On the Tanzania side, approximately 72 percent of the population in the four districts within the MRB draw water from unprotected sources: 23 percent rely on unprotected springs as a primary source of drinking water, 21 percent rely on surface water from rivers and lakes, and 28 percent rely on unprotected wells.

The vast majority of crops in the MRB are rainfed. On the Kenyan side, small-scale irrigation is practiced in a limited number of areas, and various studies have estimated that approximately 1,000 hectares are under large-scale irrigation, distributed along the river. A number of irrigation projects are in the planning stage or in early discussions with local water managers, particularly for large scale commercial agriculture farms, possibly up to an additional 5,000 hectares

(Pruijssen 2018). On the Tanzania side, less than 2 percent of the planted area is under irrigation, and the water used for irrigation is drawn using hand buckets or is gravity fed from either the Mara River or Lake Victoria. Small-scale irrigation in the MRB is typically only used to stabilize or improve yields when rains fail; it is not used more often despite water being generally available because the irrigation methods are cost and labor-intensive. While large-scale irrigation is limited in the MRB, numerous studies (e.g., Hoffman 2007, Pruijssen 2018) estimate that irrigated farms, often owned by large, foreign-owned companies, account for roughly half of the water demand in the basin.

Other major uses of water in the MRB include (in order of demand) livestock, wildlife, mining sites, and tourism operations. Currently, both the Tanzanian and Kenyan water laws and policies both pose limits on permitting processes to guarantee reserve flows for both human consumption and the ecological integrity of the river systems. Livestock in particular require large amounts of water both for drinking and feed production, and numbers have been increasing rapidly, particularly for cattle. Livestock numbers in the MRB peaked in 2008 at over 1.5 million cattle, sheep and goats, although numbers have declined since that time. Numbers of cattle, sheep and goats have increased recently, however, rebounding to 823,000 in 2016. Studies of water demand in the MRB (e.g., Hoffman 2007, Pruijssen 2018) indicate that livestock use roughly the same amount of water annually as people; livestock water demand will increase as cattle and other livestock populations increase.

INSTITUTIONAL MANAGEMENT OF WATER RESOURCES

NATIONAL POLICY

The primary regulatory document for water management In Tanzania is the Water Resources Management Act (WRMA) No. 11 of 2009, overseen by the Ministry of Water. In Kenya the primary regulatory document is the Water Act No. 43 of 2016, overseen by the Ministry of Water and Irrigation. These acts lay out the institutional structure for water management from the national level down to the community level and define the roles and responsibilities for each management level. As detailed in Table 1 for Tanzania and Table 2 for Kenya, numerous other documents lay out water sector policy and development strategy, further regulate water services providers and water quality and incorporate water considerations into sectoral planning and regulation (e.g., forestry, environmental management, climate change).

Table 1. Overview of water sector policy in Tanzania

TITLE	OVERVIEW
Water Sector Policies and Plans	
Water Resources Management Act (WRMA) No. 11 of 2009	Provides the institutional and legal framework for sustainable management and development of water resources (e.g., water courses, surface water, groundwater and estuary waters) in Tanzania. Sets out fundamental principles of water use and conservation and states preferences in water allocation (domestic purposes, environmental reserve, and socioeconomic activities). Defines the roles and responsibilities of water management institutions in Tanzania.
Water Supply and Sanitation Act No.12 of 2009	Provides the institutional and legal framework for sustainable management and adequate operation and transparent regulation of water supply and sanitation services. Establishes water supply and sanitation authorities as well as community-owned water supply organizations and details the process for appointment of service providers.
National Water Policy 2002 (NAWAPO)	Provides a comprehensive framework for the sustainable development and management of Tanzania's water resources via an Integrated Water Resource Management approach. Recommends a legal and institutional framework for managing water resources, and details water use for domestic purposes, agriculture, livestock, mining, energy, fisheries, environment, human health, wildlife and tourism, forestry and navigation.
National Water Sector Development Strategy (NWSDS) 2006–2015	Sets out how the ministry responsible for water will implement the National Water Policy to achieve *National Strategy for Growth and Reduction of Poverty* targets. The NWSDS was also intended to guide the formulation of the ministry's Harmonised National Water Sector Development Plan and the Water Sector Development Programme as inputs into the Medium Term Expenditure Framework financial planning process.
Environmental Management (Water Quality Standards) Regulations, 2007	Establishes water quality standards for eight uses of water (e.g., drinking, agriculture, fisheries, industry), as well as standards for measuring water quality and treatment of effluent.
Related Policies and Plans	
National Climate Change Strategy (2012)	Details a strategy for Tanzania to adapt to climate change and mitigate greenhouse gas emissions. Adaptation strategies are outlined for water resources, coastal and marine environment, forestry, wildlife, agriculture and food security, human health, tourism, energy (hydropower dams), industry, livestock, fisheries, infrastructure, human settlements and land use.
National Forestry Policy (1998)	Details principles for effective forest area management, conservation of forest biodiversity, water catchments and soil fertility, and enhancing national capacity to manage and develop the forest sector in collaboration with other stakeholders. The policy provides the foundation, together with the Forest Act (2002), for Participatory Forest Management, in which forests are managed through village land forest reserves, individual, group and community forests.
National Environmental Policy (1997)	A framework for environmental management that seeks to integrate environmental concerns in sectoral policies and strategies in order to ensure sustainable and equitable use of resources while preventing and controlling degradation of land, water, vegetation and air.
National Environment Management Act (2004)	Provides the legal and institutional framework for the sustainable management of the environment in Tanzania, including compliance and incentive mechanisms for environmental management. Incorporates district and village representatives in the management of environmental resources and law enforcement.
National Environmental Action Plan (NEAP) (2012–2017)	A requirement of the National Environmental Management Act, NEAPs are developed every five years to assess environmental issues, set priorities, identify the most appropriate strategies for addressing key problems, and define implementing actions to address problems.
Mara River Basin Transboundary Integrated Natural Resources Plan 2016–2026	Developed by the Lake Victoria Basin Commission, the plan provides a framework within which both strategic and operational decisions should be taken by MRB stakeholders to address threats and challenges identified in the plan.
Mara Wetlands Integrated Management Plan 2018–2022	Developed to guide management of the Mara Wetlands, the plan lays out the resource management planning process and then defines key actions that focus on the following areas: land use and wetland management; awareness raising; capacity building and governance; sustainable alternative livelihoods; water, sanitation and hygiene and research information and data needs.

TITLE	OVERVIEW
Conservation Investment Plan for Mara Wetlands	Outlines the conservation goals for the area and identifies the most critical conservation funding priorities. Serves as a tool for mobilizing new funding, including solicitation of funding for the sustainable management and conservation of the Mara Wetlands from potential donors and investors.

Table 2. Overview of water sector policy in Kenya

TITLE	OVERVIEW
Water Sector Policies and Plans	
The Water Act No.43 of 2016	Provides the institutional and legal framework for regulation, management and development of water resources and water and sewerage services in Kenya. Defines the roles and responsibilities of water management institutions in Kenya.
National Water Master Plan 2030	Developed in 2013, the NWMP assesses and evaluates the demand for and availability and vulnerability of Kenya's water resources. It proposes a plan for sustainable water resources development and management in the following areas: water supply, sanitation, irrigation, hydropower, and flood and drought disaster management.
National Water Services Strategy 2007–2015	A strategy aimed at increasing access to safe water by decreasing the distance to access water, decreasing nonrevenue water and improving the functioning of water providers, and increasing access to sewage and sanitation services. It is based on the Water Act of 2002, however, so institutional and management processes are no longer relevant.
Water (Services Regulatory) Rules, 2012	Regulation that governs provision of water services by water service boards and other operators, including licensing, infrastructure development, tariffs, reporting and inspections.
Water Quality Regulations, 2006	Provides rules relative to the use and discharge of water for domestic, agricultural and industrial purposes, makes provision for the protection of water resources from pollution and defines water quality standards.
Sub-Catchment Management Plans (SCMPs)	Lay out the plan for collaborative management of water resources and water conflict resolutions at subbasin level by the water resources user associations (WRUAs). As of 2018, there were 17 SCMPs within the MRB on the Kenyan side.
Related Policies and Plans	
Forest Conservation and Management Act No. 34 Of 2016	Provides the institutional and legal framework for the conservation and management of public, community and private forests and areas of forest land that require special protection, defines the rights in forests and prescribes rules for the use of forest land. Includes provisions for community participation of forest lands by the community forest association (CFA), the trade in forest products, the protection of indigenous forests and the protection of water resources.
National Environment Policy 2014	Details a comprehensive policy for the management of ecosystems and the sustainable use of natural resources in Kenya. Lays out an integrated approach to environmental management and recommends measures for strengthening the legal and institutional framework for effective coordination, promoting environmental management tools and supporting the implementation of the Forests Act 2005.
Climate Change Act No.11 Of 2016	Provides the institutional and legal framework for development, management, implementation and regulation of mechanisms to enhance climate change resilience and low carbon development. Establishes the Climate Change Council, Climate Change Directorate, Climate Change Fund and a requirement to develop a National Climate Change Action Plan.
National Climate Change Response Strategy 2010	Outlines a national strategy to put in place measures to address challenges posed by climate variability and change. Contains adaptation and mitigation interventions, a policy, legislation and institutional framework, as well as an action plan, implementation framework and resource mobilization plan.
National Adaptation Plan 2015–2030	Lays out a long-term plan for adaptation to climate change and provides sectoral action plans. Also calls for integrating climate change adaptation into national and county development planning and budgeting.
National Climate Change Action Plan 2013–2017	Provides an implementation framework that addresses the options for a low-carbon climate resilient development pathway. Includes enabling actions for finance, policy and legislation, knowledge management, capacity development, technology requirements, and monitoring and reporting.

MANAGEMENT OF WATER RESOURCES IN TANZANIA

Both the Tanzanian National Water Policy of 2002 and the Water Resources Management Act of 2009 recognize that access to safe drinking water is a basic human right, and that "water for basic human needs in adequate quantity and acceptable quality will receive highest priority." Per the WRMA, the Ministry of Water oversees national level water planning and strategy. Below the ministry, water resources in Tanzania are managed at five levels, from national to local: (1) national water board; (2) the nine basin water boards; (3) catchment water committees; (4) district councils; and (5) water users associations (WUAs). In practice, technical and economic powers in the water sector are delegated from the Ministry of Water to the nine basin water boards, and rural water supply regulation is delegated to the 185 district councils. The provision of water and sanitation services in rural areas is then managed by community-owned water supply organizations. Table 3 summarizes the roles and responsibilities at each level, extracted from the WRMA.

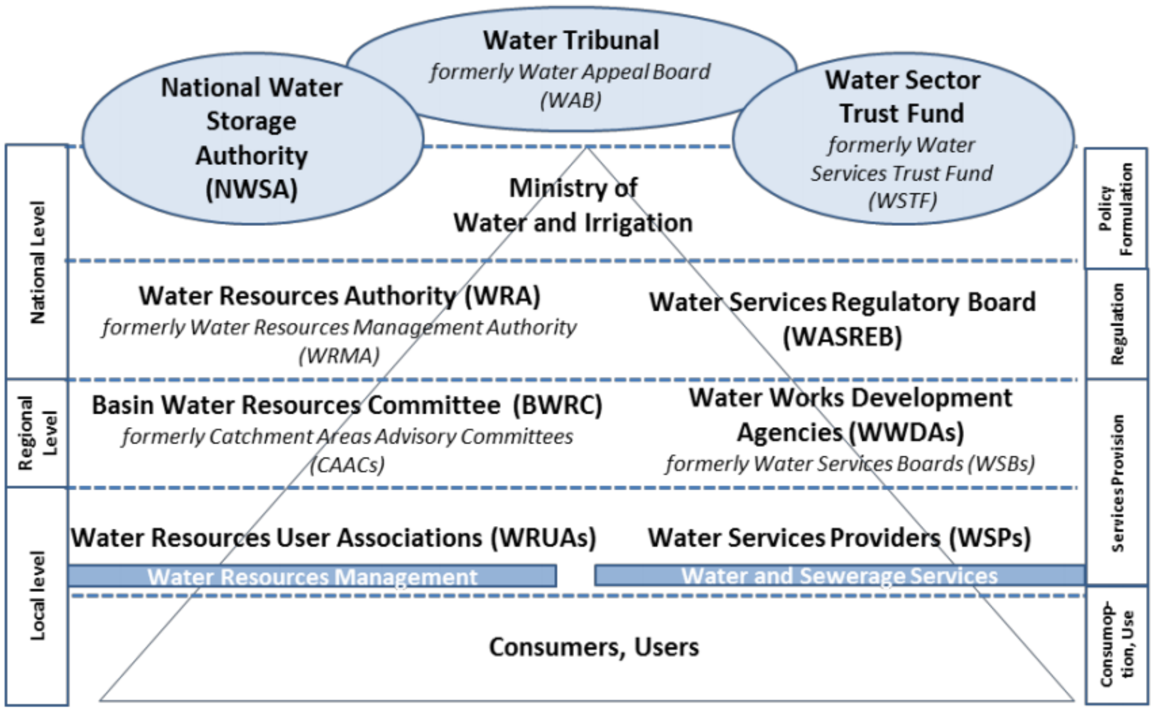
Table 3. Structure and responsibilities of water management institutions in Tanzania

INSTITUTION	ROLES AND RESPONSBILITIES
Ministry of Water	• Formulating national policy and strategy • Regulating, coordinating, supervising, monitoring and evaluating the execution of the functions
National Water Board (NWB)	• Multisectoral coordination in integrated water resources planning and management • Resolving national and international water conflicts
Basin Water Board (BWB)	• Preparing basin water resources management plans • Developing guidelines and standards for water source structures • Monitoring, evaluating and approving construction and maintenance of water source structures • Approving, issuing and revoking water use and discharge permits • Assessing and managing water resource data • Managing water use and discharge permits • Resolving intrabasin conflicts • Coordinating intersectoral water resources management at the basin level • Constituting water users associations
Catchment and Sub-catchment Water Committees	• Coordinating and harmonizing catchment or sub-catchment integrated water resources management plans • Resolving water resources conflicts in the catchment or sub-catchment
Water Users Association	• Managing, distributing and conserving water from a source used jointly by the members of the association • Acquiring and operating under any permits • Resolving conflicts between members of the association related to the joint use of water or a water resource • Collecting water user fees on behalf of the basin water board • Representing the special interests and values arising from water used for public purposes, such as in an environmental or conservation area or for managing a groundwater control area

MANAGEMENT OF WATER RESOURCES IN KENYA

Kenya's 2010 Constitution acknowledges access to clean and safe water as a basic human right and assigns responsibility for water and sanitation supply to its newly devolved political governance system of the 47 counties, with budgetary support and oversight roles assigned to the national government. As noted in Table 2, the 2016 Water Act defines the structure of water management institutions (see Figure 2), lays out roles and responsibilities (detailed in Table 4), and aligns the process of devolution to the water sector specifically.

Figure 2: Hierarchy of water institutions under Kenya's 2016 Water Act



Source: World Bank Group, 2016

Table 4. Structure and responsibilities of water management institutions in Kenya

INSTITUTION	ROLES AND RESPONSIBILITIES
Water Tribunal	• A subordinate court that hears and determines cases presented by a person or institution directly affected by the decision of the Cabinet Secretary, the Authority and Regulatory Authority or any person acting under these authorities.
National Water Harvesting and Storage Authority	• Developing the national public waterworks for water resources storage and flood control • Maintaining and managing national public waterworks infrastructure for water resources storage • Collecting and providing information for formulation by the Cabinet Secretary of the national water resources storage and flood control strategies • Developing a water harvesting policy and enforcing water harvesting strategies • On behalf of the national government, undertaking strategic water emergency interventions during drought • Advising the Cabinet Secretary on any matter concerning national public waterworks for water storage and flood control
Water Sector Trust Fund	• Financing community initiatives for the sustainable management of water resources • Enhancing development of water services in rural areas considered not commercially viable for provision of water services by licensees • Developing water services in underserved poor urban areas • Researching activities in the area of water resources management and water services, sewerage and sanitation
Ministry of Water and Irrigation	• Formulating policy and strategies for water and sewerage services • Coordinating and monitoring of other water services institutions • Developing overall plans for sector investments, planning and resource mobilization
Water Resources Authority (WRA)	• Formulating and enforcing standards, procedures and regulations for the management and use of water resources and flood mitigation • Reviewing, issuing and enforcing water permit applications for water abstraction, water use and recharge • Determining, setting and collecting water permit fees and water use charges • Providing information and advice to the Cabinet Secretary for formulation of policy on national water resource management, water storage and flood control strategies • Coordinating with other regional, national and international bodies for the better regulation of the management and use of water resources
Water Services Regulatory Board (WSRB)	• Determining and prescribing national standards for the provision of water services and asset development for water services providers • Evaluating and recommending water and sewerage tariffs to the county water services providers and approving the imposition of such tariffs in line with consumer protection standards • Setting license conditions and accrediting water services providers • Monitoring and regulating licensees and enforcing license conditions • Developing a model memorandum and articles of association to be used by all water companies applying to be licensed by the Regulatory Board to operate as water services providers • Monitoring compliance with standards including the design, construction, operation and maintenance of facilities for the provision of water services by the waterworks development bodies and the water services providers • Advising the Cabinet Secretary on the nature, extent and conditions of financial support to be accorded to water services providers • Monitoring progress in the implementation of the water strategy • Maintaining a national database and information system on water services • Establishing a mechanism for handling complaints from consumers regarding the quality or nature of water services

INSTITUTION	ROLES AND RESPONSIBILITIES
Water Services Regulatory Board (WSRB) ***(cont.)***	• Developing guidelines on the establishment of consumer groups and facilitating their establishment • Inspecting waterworks and water services to ensure that such works and services meet the prescribed standards • Reporting annually to the public on issues of water supply and sewerage services and the performance of relevant sectors • Developing regulations on water services and asset development which shall include business, investment and financing plans in order to ensure efficient and effective water services and progressive realization of the right to water services • Advising the Cabinet Secretary on any matter in connection with water services • Providing recommendations on providing basic water services to marginalized areas

Basin Water Resources Committee (BWRC)	• Providing overall management of the catchments
	• Facilitating establishment of water resources user associations (WRUAs)
	• Advising WRA and county governments on the following:
	    • Conservation, use and apportionment of water resources
	    • Granting, adjustment, cancellation or variation of any permits
	    • Protection of water resources and increasing the availability of water
	• Reporting annually to the users of its services and the public on water issues and their performance within the basin area
	• Collecting and analyzing data, and managing the information system on water resources
	• Reviewing the basin area water resources management strategy
	• Undertaking flood mitigation activities
	• Coordinating information sharing between the basin area and the WRA
	• Developing water allocation plans to promote equitable water sharing within the basin area

Water Works Development Agencies (WWDAs)	• Developing, maintaining and managing the national public waterworks within its area of jurisdiction • Operating the waterworks and providing water services as a water service provider, until such a time as responsibility for the operation and management of the waterworks are handed over to a county government, joint committee, authority of county governments or water services provider within whose area of jurisdiction or supply the waterworks is located • Providing technical services and capacity building as may be requested by county governments and water services providers within its area
Water Resources User Associations (WRUAs)	• Community-based associations for collective management of water resources and resolution of conflicts concerning the use of water resources • The BWRC may contract WRUAs as agents to perform certain duties in water resource management
Water Services Providers (WSPs)	• Providing water services within the area specified in their licenses and developing county assets

VULNERABILITY

The fate of MRB's inhabitants, and the ecosystems on which they rely, will depend on the interplay of population pressure, economic development, urbanization, land use changes (including deforestation and land degradation) and changes in water quantity and quality. Each is linked to the others, which poses complex problems for managing land and water resources. As populations grow or move to cities, their demand for water resources changes. Climate variability and change will multiply these pressures on water resources.

This climate change vulnerability assessment for the MRB aims to shed light on the pressures that face the MRB and to offer insights on priority vulnerabilities of the MRB as a whole. This information provides the evidence base to support climate resilient investments across the basin, many of which also reflect those highlighted by key stakeholders in the Nyangores sub-catchment and the Mara Wetlands (see case studies in Annexes A and B).

Vulnerability is a function of exposure, sensitivity and adaptive capacity, where:

- *Exposure* is a function of location and represents the direct and indirect risk posed by weather- and climate-related hazards and other pressures such as population growth, land use and land cover changes.
- *Sensitivity* is the propensity to be adversely affected by weather and climate-related hazards.
- *Adaptive capacity* is a function of the tools and resources available for stakeholders to respond to current stresses and prepare for future stresses.

The IPCC (2007) defines vulnerability as:
"The degree to which a system is susceptible or unable to cope with the adverse effects of climate change, including variability and climatic extremes."

METHODS

The assessment addresses these components of vulnerability by answering several critical questions:

- To what climate risks are basin users vulnerable? How will this vulnerability change under a changing climate? (exposure)
- What sectors/livelihoods of the basin are vulnerable and why? (sensitivity)
- What resources are available to cope with and confront current and future risks? (adaptive capacity) *Note: The adaptive capacity component is addressed through the institutional management section and is therefore excluded from the spatial analysis presented here. The rationale for this decision is that available livelihood information is limited for the region and varies between countries, posing significant challenges to the use of a spatial level analysis to address this component.*

The vulnerability indicators are defined in Table 5. The aim was to select straightforward indicators that could offer timely and ongoing assessments of climate risks to inform adaptation across the basin. The analysis was carried out at the sub-basin (hydrological unit) scale (Figure 1).

Table 5. Indicators of vulnerability[4]

CATEGORY	RATIONALE	INDICATORS
Exposure	Represents the direct risk from climate-related hazards and is a function of location.	• Trends in temperature and rainfall as well as extreme events across the basin
Sensitivity	Represents the propensity to be adversely affected by weather and climate events. For example, farmers reliant on rainfed agriculture are more sensitive to climate variability and change than people employed in urban areas and relying on this employment for food.	• Population density and trends • Livestock and wildlife dynamics • Land use changes
Future Risk	Includes variables related to principal risks under a changing climate, such as rising temperatures and increased intensity of rainfall events.	• Projected temperature rise by 2030 and 2050 • Projected changes in rainfall by 2030 and 2050

DETAILED METHODOLOGICAL APPROACH FOR INDIVIDUAL VARIABLE CALCULATIONS

Human population

The 2012 human population data were sourced from Kenya National Bureau of Statistics and the 2009 censuses from the World Resources Institute. The human population data for Tanzania were sourced from the Tanzania Bureau of Statistics. In Tanzania the census was conducted in 2002 and 2012.

The censuses for Kenya and Tanzania were conducted at different times. In Kenya the census was conducted in 1962, 1969, 1979, 1989, 1999 and 2009, with the next one scheduled for 2019. In Tanzania the data available were from 2002 and 2012. Mapping these data required harmonization of the time periods available for both countries. For example, a 2012 map of population was derived using the average annual population growth rate between the 1999 and 2009 censuses, which was 3.65 percent. This growth rate was used to project population numbers by sub-catchment for 2018 and 2030. Similarly, population growth rates for Tanzania were calculated from the censuses of 2002 and 2012. Based on the average annual growth rate of 4.76 percent, population numbers for 2018 and 2030 were projected.

Population size for a target year without a census (P_{t2}) was estimated from that for a year with a census (P_{t1}) using:

$$\boldsymbol{P_{t2} = P_{t1}e^{rt}}$$

Where r = $(p_2/p_1)/t$—the average annual population growth rate between the two reference years, and $t = t_2 - t_1$ years.

At the spatial scale, the population was aggregated to the hydrological unit and relative densities recalculated to reflect the new areas.

[4] Data sources are listed in Boxes 1 and 2. For a complete data list by name, see Annex 3.

Land use and land cover changes

Vegetative cover supports the Earth's ecosystems. It regulates the water, carbon and nitrogen flows in the biosphere and affects soil characteristics. The most important ecosystem processes in the MRB are dictated by the land cover and exemplified by vegetation heterogeneity and the diversity of land use. In the MRB, land use includes traditional pastoralism, agro-pastoralism, large- and small-scale cultivation agriculture, forest, wildlife conservation, mining and fishing.

The derivation of land cover and land cover changes in the MRB was based on the interpretation of 2015 (Landsat 8) and 1995 (Landsat 5) images as part of the African BioServices project. The purpose of this exercise was to determine the changes in land use and cover in the past 20 years. The image interpretation was based on delineating the sample from Google Earth, verifying them on the ground and running a classier. More than 500 points were visited on the ground: half were used to classify the image and half to verify the land cover derived. In the study Random Forest was used to classify the 2015 and 1995 images and classes were based on Grunblatt et al. (1989). The major land cover categories defined and examined include forest, woodland, shrubland, riverine, agriculture, built-up areas, wetlands and swamps.

Assumptions and limitations

Assumptions in this methodology include the following:

- The main driver for the local climate is the larger-scale regional climate of East Africa and other factors such as the El Niño Southern Oscillation (ENSO). Some factors, however, may still be unresolved.
- Global Climate Models (GCMs) are adequate to accurately simulate the large-scale climate. If the GCM fails to do so, the errors can propagate through the downscaling process. Similarly, if the quality of the observation data used to derive the statistical relationship is poor, this will affect the projections.
- The relationship between the large-scale drivers and local climate will be the same in the future as in the past. This is likely of greatest concern for long-term projections, whereas near-term projections often assume climate stationarity (wherein the near-future climate dynamics will be the same as the past).

Modeling uncertainties

Our understanding of the climate system is limited, as are our methods to project climate. As spatial scales become finer, more uncertainties are introduced into the modeling, and the range of possible climate responses therefore widens. Sources of uncertainty include:

- *Natural variability:* It is not possible to accurately define the limits of natural variability due to the short time that historical records have been kept, and because the climate system is chaotic. Uncertainty cannot be reduced, meaning that climate scientists need to evaluate a range of possible futures.
- *Future emissions:* The range of possible societal development pathways will affect greenhouse gas emissions and other environmental forcing factors. Two dominant emissions scenarios used in planning: RCP 4.5 represents an emissions pathway that

stabilizes before 2100, with emissions peaking around 2040. RCP 8.5 represents a high-emissions future where emissions continue to increase (Moss et al., 2010).

- *Uncertainty in the science:* Gaps in the current knowledge and understanding of the dominant physical processes controlling the regional climate system and how these processes might change in the future.
- *Structural uncertainty:* Tools and methods are imperfect, and their application is sometimes inappropriate.
- *Observational uncertainties*: Inaccurate information may be used as input into the climate modeling and used to test the results.

The best way to understand the possible range of projected changes is to combine as many models as reasonably possible under one emissions pathway; what results is a range of likely change. This leads to a more defensible projection of the direction of change, even though the size of the projected change is less certain. For the reasons stated above, where projections of change are provided in this report, these incorporate a subset of GCMs and RCMs used in the latest IPCC report (CMIP5). This shows the spread of projections across the models, rather than taking a single-point projection approach.

EXPOSURE OF THE BASIN TO CLIMATE RISKS

The findings of the Intergovernmental Panel on Climate Change (IPCC) fifth assessment report for East Africa (Niang et al. 2014) point out the following trends in temperature and precipitation extremes since the 1950s, with 1961–1990 used as a baseline:

- Spatially varying trends in most areas for minimum temperatures, with some areas seeing more pronounced increases in minimum temperatures than others—*medium confidence*
- Spatially varying trends in dryness, with some areas experiencing more frequent or extreme dry episodes than others—*low confidence*

The analysis of temperature and rainfall is based on these regional insights and the data sources in Box 1. Background and supplementary information also included model information for Kenya and Tanzania and the experiences of farmers and stakeholders consulted in the Nyangores sub-catchment and the Mara Wetlands in September 2018.

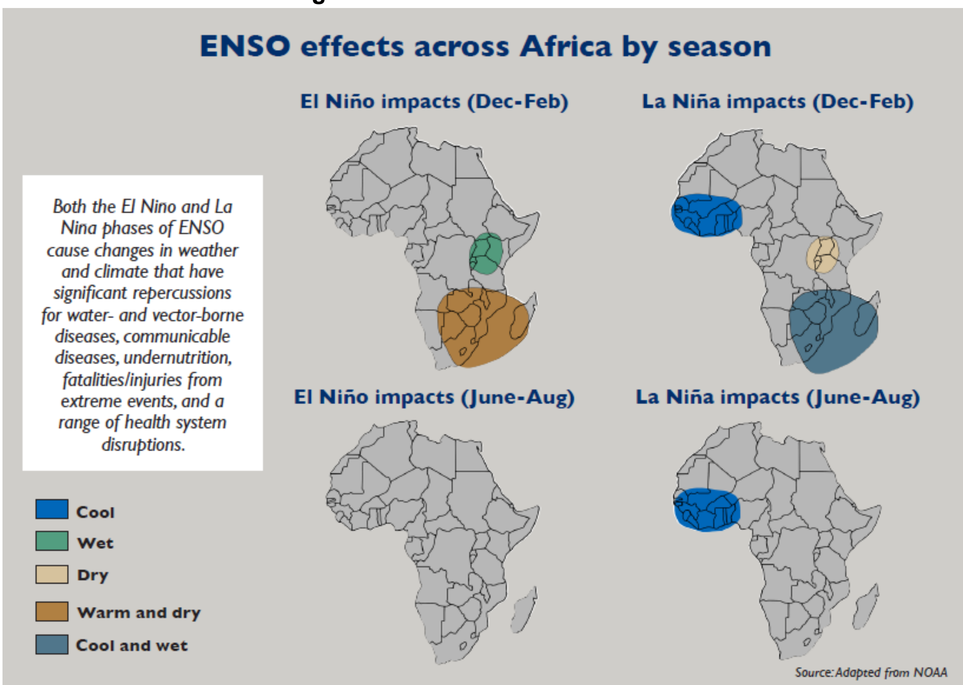
BOX 1: Data sources for temperature and rainfall climatology

- ***Temperature*: The Climate Research Unit (CRU TS 3.21; Harris et al., 2014) data are sourced from over 4,000 global weather stations; they are available for the period 1995–2012 and are gridded to a 0.5 x 0.5 degree (roughly 55 km on a side) spatial resolution. The CRU data are, however, limited in accuracy by the availability of station records, and this is particularly acute in the MRB. Nevertheless, this information can point to trends in temperatures and critical information to conduct baseline assessments. Because the CRU data are monthly, daily statistics such as exceedances of specific thresholds cannot be calculated.**
- ***Rainfall*: Climate Hazards Group InfraRed Rainfall with Stations daily rainfall data (CHIRPS; Peterson et al., 2013) are a combination of satellite, re-analysis, and weather station rainfall data for the period 1981–2014, gridded to a 0.05 x 0.05 degree (roughly 5 km) spatial resolution. As with all such data, interpretation of results should be done with due caution.**

CLIMATOLOGY AND CLIMATE VARIABILITY

Situated in the intertropical zone, the MRB's climate is strongly influenced by the Intertropical Convergence Zone (ITCZ) and Indian Ocean sea surface temperatures, which can influence the onset, duration and intensity of rainfall. Rainfall patterns are dominated by interannual and decadal rainfall variability, alternating between periods of both above-normal and below-normal rainfall—with droughts occurring every 5–7 years—and variability also subject to the El Niño Southern Oscillation (ENSO), a cyclical variation in the surface temperature of the tropical eastern Pacific Ocean. The timing between ENSO events varies, but typically an El Niño or La Niña occurs once every two to seven years. El Niño is associated with higher-than-normal rainfall in East Africa from October to December, while La Niña is associated with drier-than-normal conditions from December to February (Figure 3). However, these associations vary at finer scales and they are not always apparent.

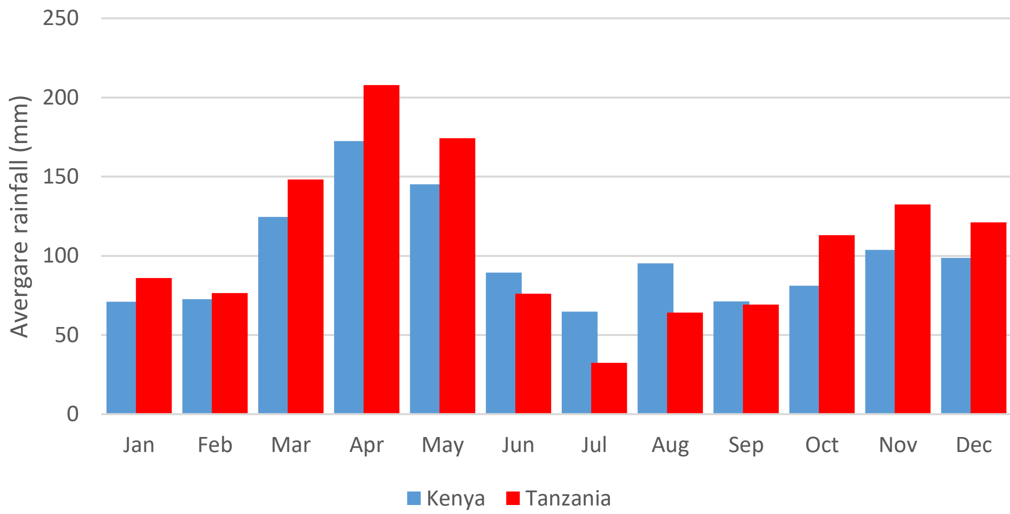
Figure 3: Effects of ENSO in Africa



Source: USAID (2017)

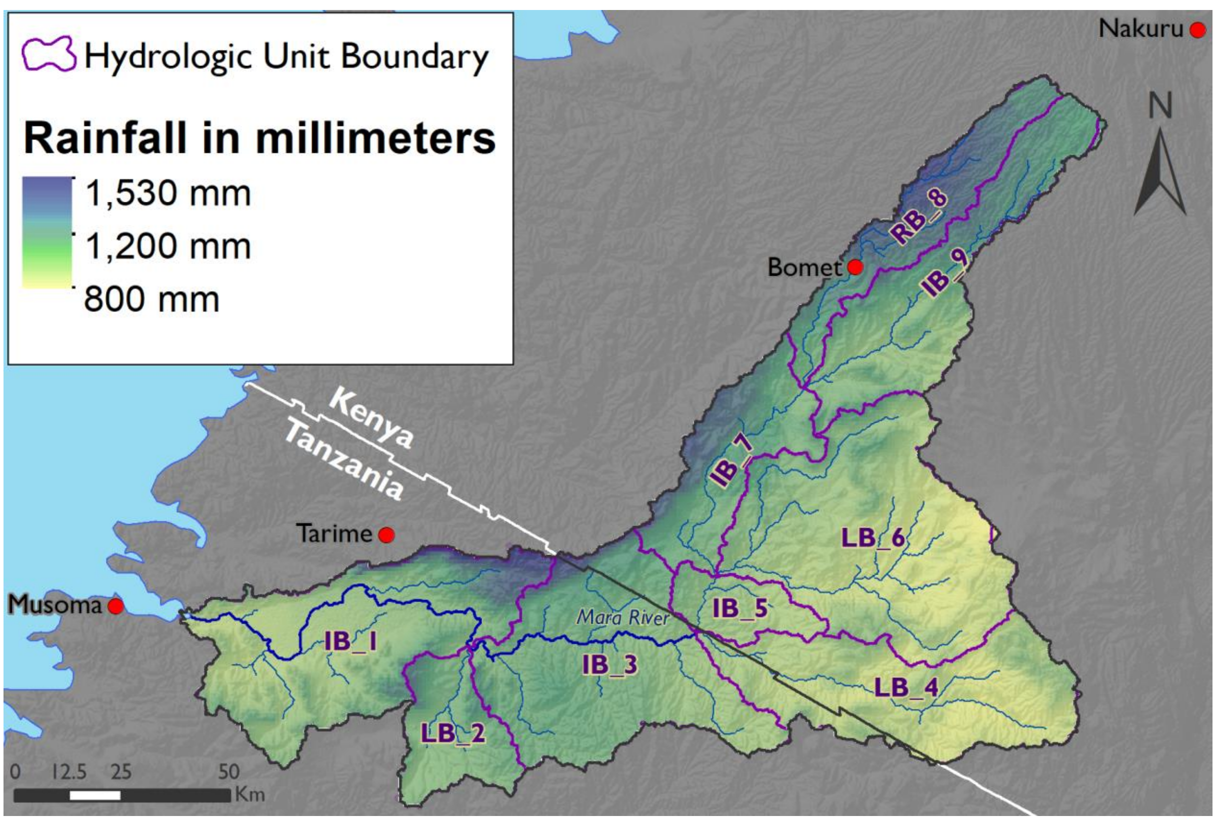
A bimodal rainfall pattern—or two rainy seasons—is generally recognized in the MRB, with short rains driven by the southward migration of the ITCZ between October and December and long rains as the ITCZ returns northward between March and June (Figure 4). The seasonality of rainfall and temperature varies by catchment, as does total monthly rainfall and average monthly minimum and maximum temperatures. Rainfall decreases as altitude decreases on a west–east gradient, with the higher reaches of the basin near the Mau forest escarpment receiving on average 1,000–1,750 mm per year, 900–1,000 mm per year in the middle regions including the Masai Mara and Serengeti reserves and the driest areas near the Mara Wetlands, receiving 300–850 mm per year (Figure 5 shows average values across the basin). Similarly, temperatures increase as the altitude decreases—with the highest temperatures in the central rangelands and southern wetland reaches of the basin (Figure 6 shows average values across the basin).

Figure 4: Average annual rainfall in the Kenya and Tanzania areas of the Mara River Basin between 1960 and 2014



Source: World Bank Climate Knowledge Portal

Figure 5. Average annual rainfall distribution in the Mara River Basin



Note: Data used for Figures 6, 7 and 8 are from WorldClim Global Climate Data

Annual mean, maximum and minimum temperatures across the MRB for the period 1991–2015 (Figures 6 and 7) exhibit spatial variability with topography. Mean annual temperatures are lower in the north basin, ranging between 18°C and 20°C, and increase toward the south, with mean annual temperatures in the rangelands from 19°C to 22°C and in the wetlands from 22°C to 24°C.

Figure 6. Average annual maximum temperature in the Mara River Basin, 1991–2015

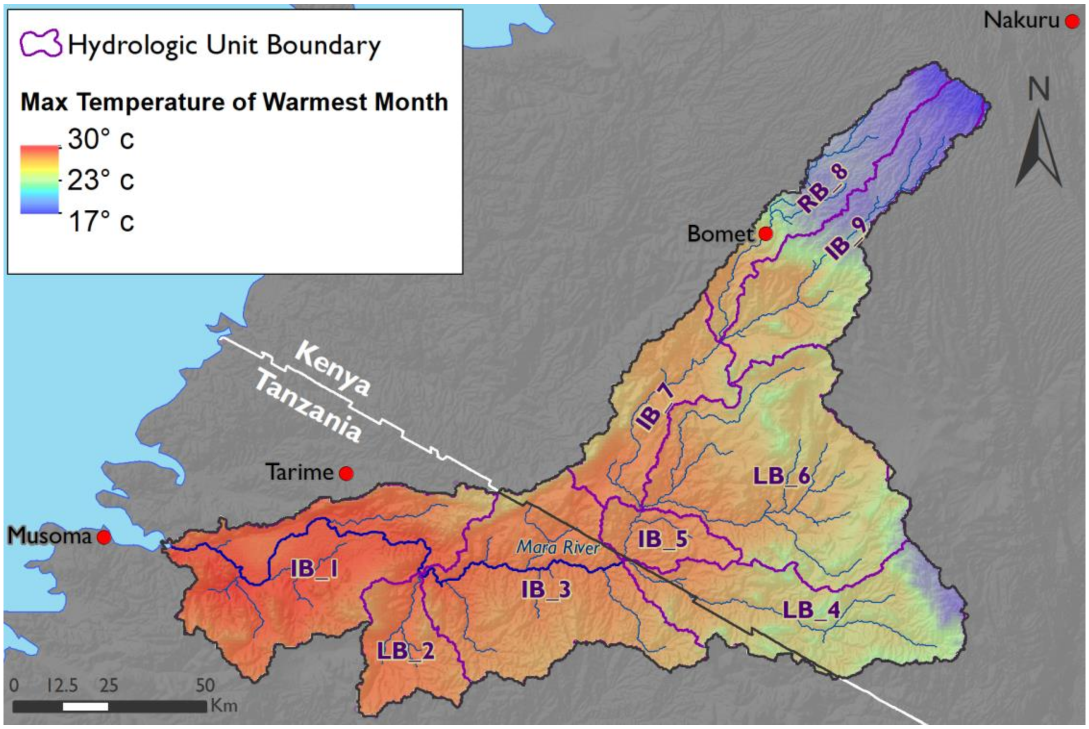
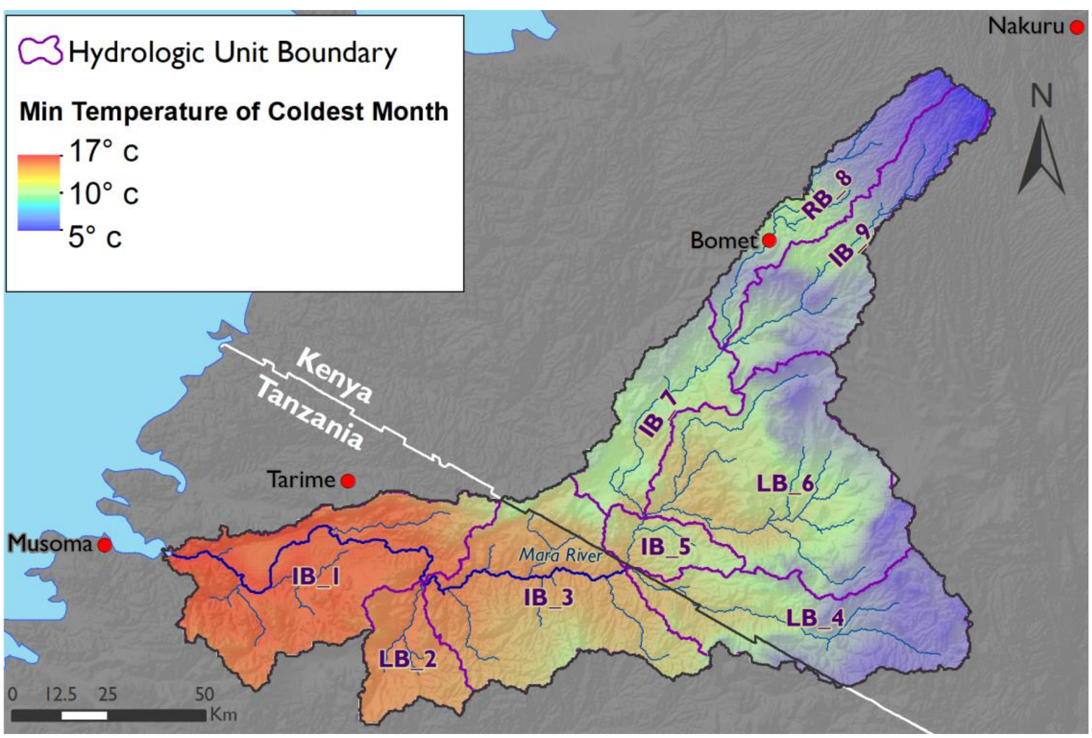
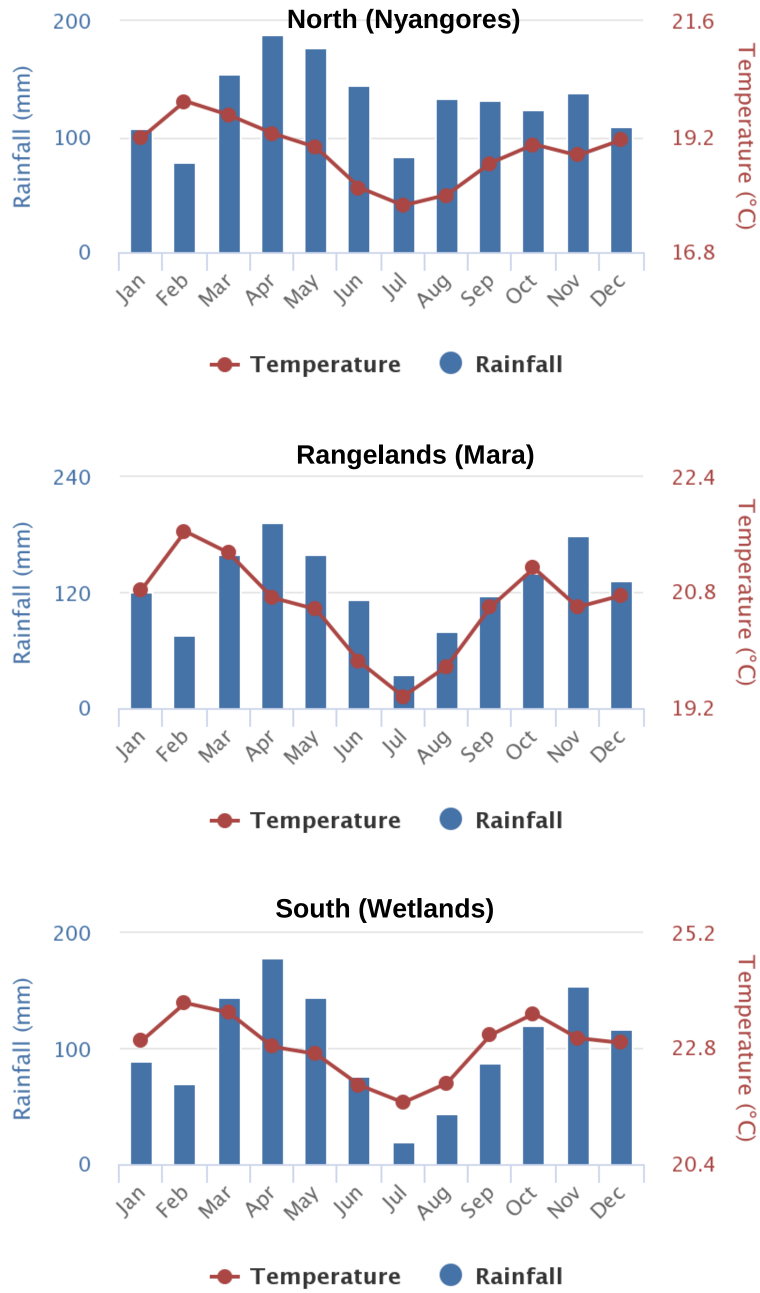


Figure 7. Average annual minimum temperature in the Mara River Basin, 1991–2015



Monthly mean temperatures peak following the short rains (October–December); the hottest months are January to March in both the northern basin (the Nyangores River) and the rangelands (the Mara River). A second peak in monthly temperatures occurs in the wetlands in October. The coldest months occur toward the end of the long rains (July), when monthly mean minimum temperatures often drop below 18°C (Figure 8).

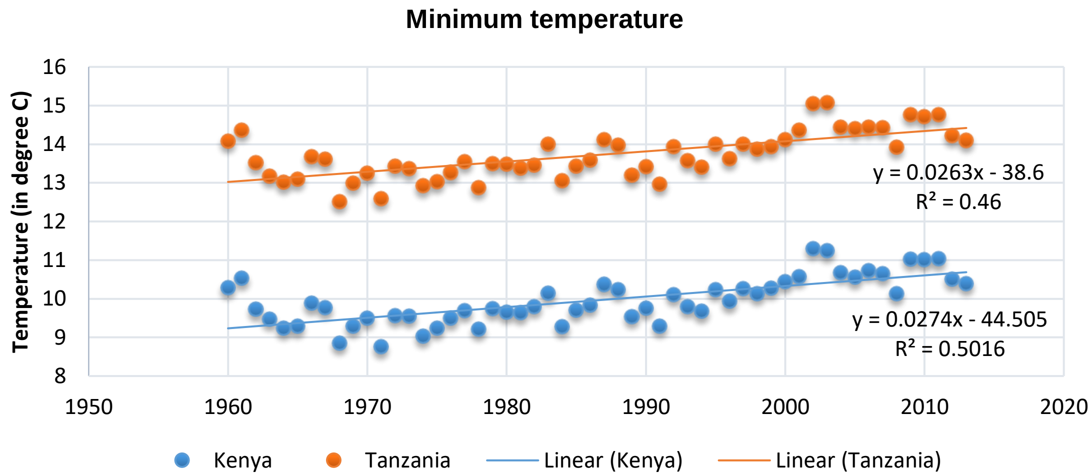
Figure 8. Average monthly rainfall and average temperature in the Mara River Basin, 1991–2015



Source: [World Bank Climate Knowledge Portal]

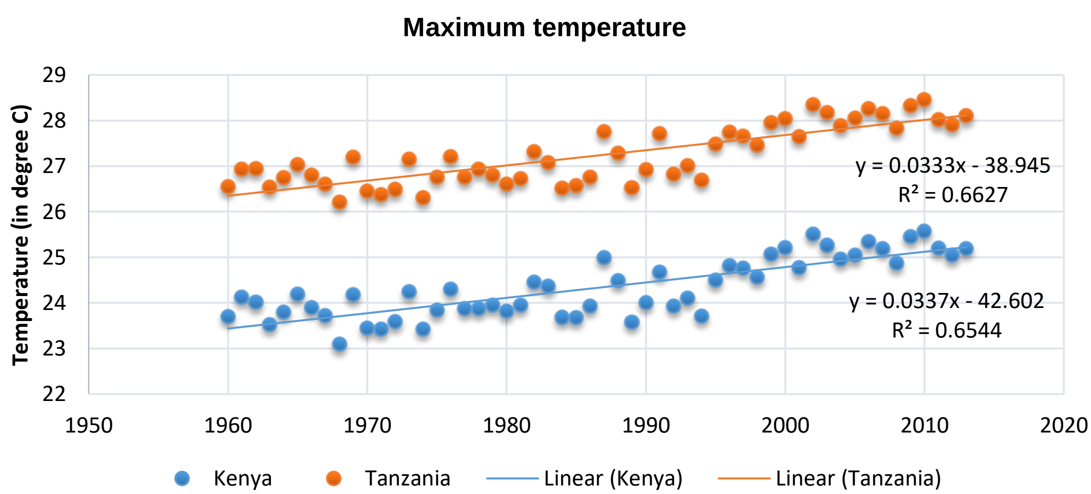
The time series of the land-area-averaged seasonal temperature trends between 1960 and 2014, derived from the CRU TS3.21 dataset, show trends in both minimum and maximum temperatures for the MRB, and indicate a warming trend of 1°C–1.5°C. Recent studies of Kenya also point to the greatest increases in recorded temperatures occurring between March and May, and corresponding with the long rains (USAID 2017a, 2017b). These changes are pertinent to temperature-sensitive sectors such as health, for example, where warmer nights (minimum temperatures in Figure 9) can alter the geographic suitability of vector-borne diseases, such as malaria, increasing exposure at higher elevations, where exposure has been limited. In fact, members of the Community Forest Association in the upper Nyangores sub-catchment have noted an increase in malaria cases since the late 1990s. Warmer daytime temperatures (Figure 10), in addition, can increase evaporation from critical water points, drying out some areas while the evaporated water falls as excess rain in others.

Figure 9. Trends of annual minimum temperature for the Mara River Basin for Kenya and Tanzania



Source: CRU TS3.21 dataset

Figure 10. Trends of annual maximum temperature for the Mara River Basin for Kenya and Tanzania



Source: CRU TS3.21 dataset

Additional trends noted by participants in the case studies are more difficult to verify using climate information but are nonetheless relevant for the assessment of risks. These include:

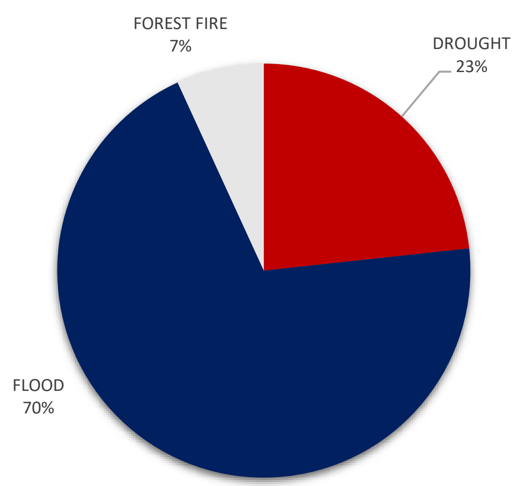
- ***Increasingly unreliable growing seasons***—The length of time that soil temperature and soil moisture conditions are suitable for cash and subsistence crops is becoming less reliable, with delayed starts and more frequent failure of the long and short rains. Farmers, for example, now plant maize throughout the year, rather than relying on the historical long rains as they become increasingly unreliable.
- ***Increases in extreme events, including more intense rainfall events or longer dry periods***—All crops grown in the Nyangores sub-catchment are sensitive to rising temperatures, which can increase evaporation and reduce yields. Droughts and intense rainfall events also pose a risk to production.

HISTORICAL OCCURRENCE OF EXTREME EVENTS THAT IMPACT THE BASIN

Historically, weather-driven events in the MRB have affected the livelihoods of the basin's inhabitants and wildlife in the area. These events include, in order of prevalence of recorded events in the Kenyan counties in the basin: floods, droughts, forest fires and landslides (Figure 11). These events follow the basin's rainfall climatology as follows:

- Floods, a function of heavy rainfall, have been recorded during both the long and short rains, with most events in April during the long rains.
- Droughts occur throughout the year but are concentrated historically in the months of March, April, and August.
- Forest fires, primarily a function of prolonged dry conditions, and set by either people clearing forests or lightning were recorded in Nakuru County.
- Landslides due to heavy downpours were recorded in Narok County.

Figure 11. Disasters in Bomet, Narok and Nakuru counties in Kenya, 1997–2017



Source: Desinventar Kenya database[5]

[5] https://www.desinventar.net/DesInventar/profiletab.jsp

These reflect the experiences of community members in the Nyangores basin, who noted that:

- In the upper Nyangores, ***drought and disease (both crop and livestock)*** were priority risks. Maize and potato, both non-native crops, were most at risk from climate change: maize was ranked highly vulnerable to droughts and disease, and potato, moderately vulnerable to land use change and flooding.
- In the lower Nyangores, ***drought and flooding*** were priority risks. Maize, beans and cattle were the resources most as risk from climate change, ranking particularly vulnerable to drought, flooding and disease.

Although similar quantitative data are not readily available for Tanzania, participants at the recent vulnerability assessment workshop in the MRB noted that drought and disease (both human and animal) were priority risks to crops, livestock, fisheries and human health. Furthermore, livestock was seen as the resource most at risk from climate change, ranking highly vulnerable to drought and disease, and moderately vulnerable to flooding and land use change.

CLIMATE PROJECTIONS

This analysis makes use of available climate information from various sources, including, the Intergovernmental Panel on Climate Change 5th Assessment Report, the Regional Climate Model Projections from USAID 2017, and downscaled climate projections from Ramirez et. al, 2010.

Summary

Projected changes in temperature and rainfall of relevance to the MRB are summarized in Table 6. A detailed analysis follows, which includes both an annual and seasonal perspective on the projected changes in rainfall and temperature across the basin.

Table 6. Temperature and rainfall projections for the Mara River Basin

TEMPERATURE	
Historical	**Projected changes, 2020–2050**
• An average rise of 1°C–1.5°C between 1960 and 2014 for minimum and maximum temperatures across the basin • Increased average temperature of 0.34°C per decade from 1985 to 2015; with the greatest increases March to May and in arid and semiarid regions of Kenya	• Increase in average temperature between 0.7°C and 1.97°C by 2030, and 1.5°C to 2.71°C by 2050 across the basin with warming greatest during the months corresponding to the long rains. • Increased duration of heat waves in Kenya (by 9 to 30 days) and in Tanzania (by 7 to 22 days)
RAINFALL	
Historical	**Projected changes, 2020-2050**
• Little change in average annual precipitation but declines in the long rains have been seen across the basin since the 1970s • More frequent intense rainfall events and less reliable rains across the basin	• Increase in average rainfall (projections range from -3 to +28 percent), mainly from October to May and in the highlands • Increased interseasonal rainfall variability • Continued increase in the frequency and intensity of heavy rainfall events

East African Context

Climate change projections that span the range of possible climate futures (see Box 2) are taken from a subset of available output of the latest generation of Global Climate Model (GCM) experiments. These were evaluated at a regional (East Africa) scale in the IPCC Fifth Assessment Report. The highlights of the IPCC report of relevance for East Africa are summarized here:

- Temperature projections range from approximately no change to 4°C warmer conditions in both December–February and June–August seasons by 2050. Lower temperature increases are more likely under a low-emissions (RCP 4.5) scenario and higher temperature increases are more likely under a high-emissions (RCP 8.5) scenario (Figure 12).
- Projected changes in temperature vary spatially: under the RCP 4.5 emissions scenario, northern regions of East Africa are projected to warm more than other regions, continuing the observed trends (Figure 13). The IPCC report states "it is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase."
- Projections of rainfall change are uncertain, and there is disagreement among the model simulations on the likely direction and magnitude of change. Historical interannual, decadal and multidecadal time scale variability is expected to continue to be the dominant influence on future rainfall. Approaching 2100, some models point to slightly wetter conditions on average over East Africa, in particular under the high RCP 8.5 emissions scenario, however other models project drier-than-average conditions (Daron 2014).

BOX 2: EXAMINING FUTURE TEMPERATURE AND RAINFALL: DATA SOURCES AND SCENARIOS

To explore the influence of emissions, climate, environmental change and vulnerability on the planet, the IPCC uses scenarios, termed Representative Concentration Pathways (RCPs). These include: RCP 8.5, RCP 6, RCP 4.5, and RCP 2.6. The numbers refer to radiative forcing, a measure of how greenhouse gases in the atmosphere change the Earth's normal energy balance. This information is translated through models of climate dynamics and used to project how much the Earth will heat because of increased greenhouse gases.

This report uses two of these scenarios to represent a moderate and worst-case evolution of climate.

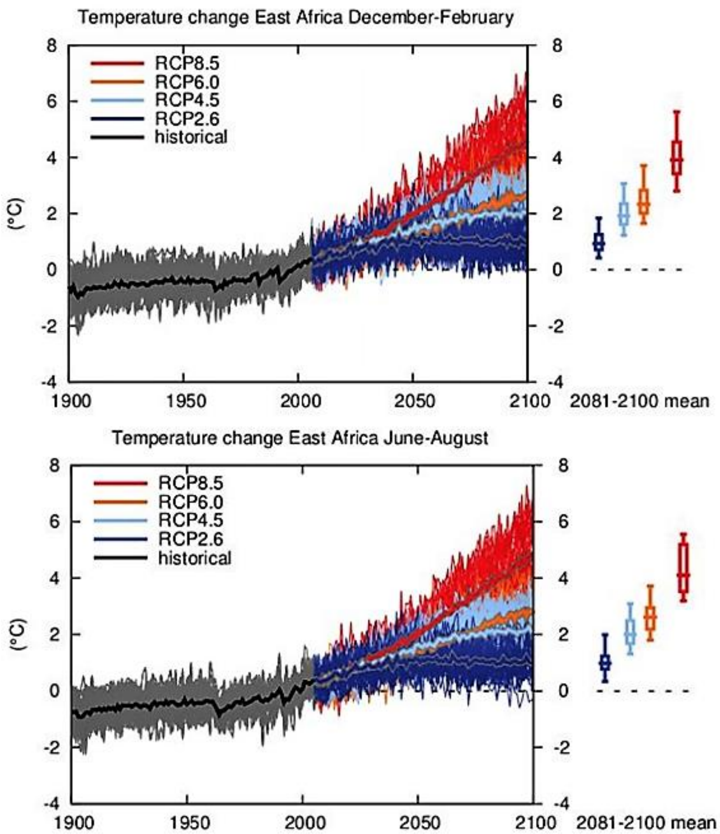
- **RCP 4.5—indicative of the current evolution of climate to date and a realistic best-case scenario (RCP 2.6, while included in the figures in this assessment, requires a major decrease in global GHG emissions)**
- **RCP 8.5—a measure of the worst-case scenario**

These scenarios are evaluated using a multimodel ensemble of 11 global circulation models from the Coupled Model Intercomparison Project (CMIP5) and downscaled to a resolution of 5 degrees using the delta method. This evaluation method supports the bulk of the analysis presented here. This information is also complemented by information from regional climate models (RCMs) for the region, which are sourced from two GCMs (HadGem2 and ICHECH) and two RCMs (KNMI and CCLM4), all driven by the RCP 8.5 scenario.

Two future time periods were examined: 2030 and 2050. Changes in seasonal climate patterns add another level of complexity, and the differences between projections for the long and short rains are important for the MRB. Three "seasons" were examined in detail:

- **the short rains (corresponding to October to December)**
- **the long rains (corresponding to March to June)**
- **a dry period occurring between July and September**

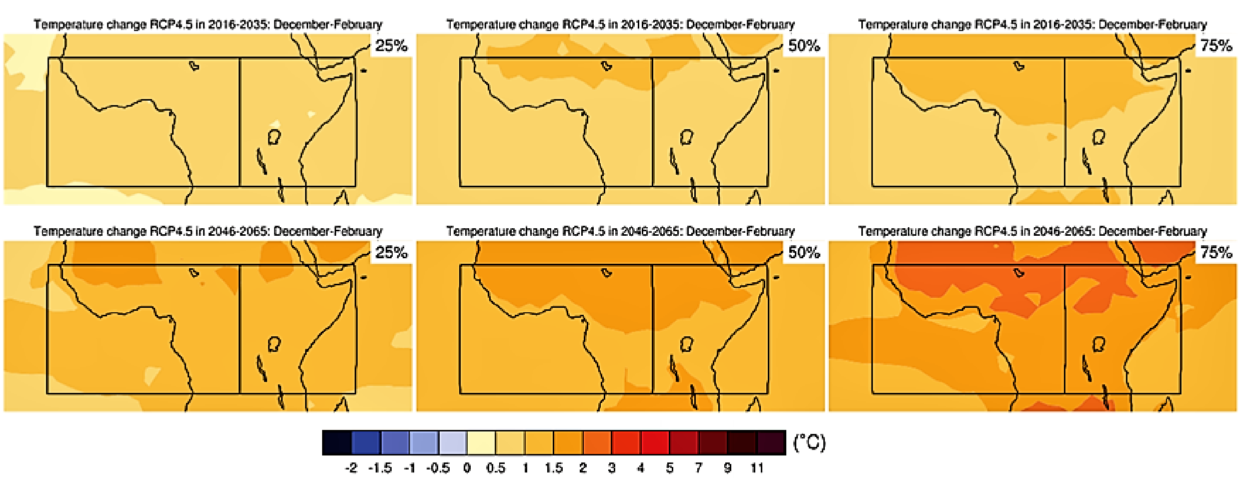
Figure 12: Time series of temperature change relative to 1986–2005 averaged over land grid points in December–February and June–August



Source: [IPCC Atlas of Global Change Projections.]

Note: Thin lines denote one model simulation and thick colored wedges are the multimodel mean. On the right the 5th, 25th, 50th, 75th and 95th percentiles of the distribution of 20-year mean changes are given for 2081–2100 for the four RCP scenarios.

Figure 13: Maps of temperature change in East Africa in December to February for 2016–2035 and 2046–2065 with respect to 1986–2005, according to the RCP 4.5 scenario



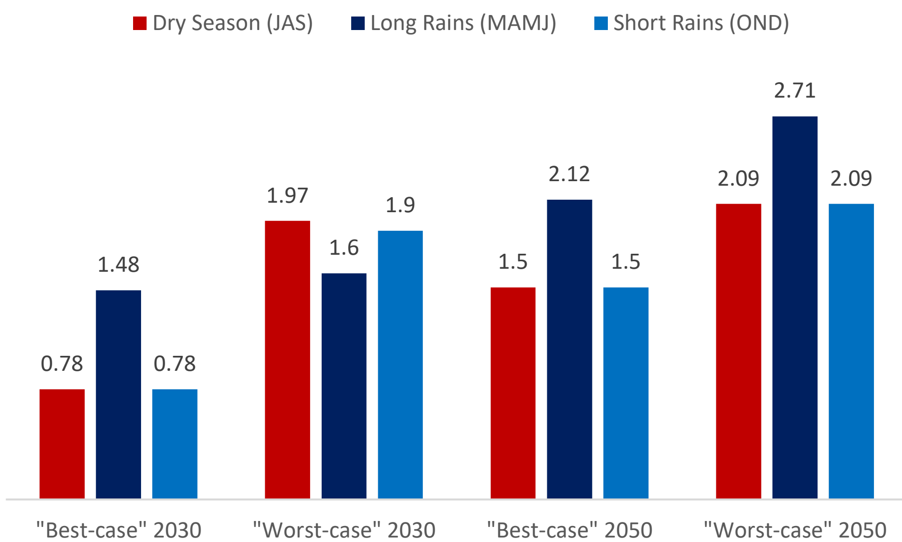
Source: [IPCC Atlas of Global Change Projections]

Note: The left column show the 25th percentile (i.e., a quarter of models are below these values), the middle column shows the median and the right column shows the 75th percentile (i.e., a quarter of models are above these values).

Temperature

The climate of the MRB is projected to get warmer, part of a larger pattern of warming in sub-Saharan Africa and the world. The multimodel ensemble used in this analysis points to temperatures increasing on average between 0.78°C and 1.97°C by 2030 and 1.5 to 2.71°C by 2050, with the highest range in temperature increases during the months of the long rains (Figure 14). These average values, however, mask the much larger range of projected temperature increases, which vary between 0.5°C and 5°C between 2020 and 2060.

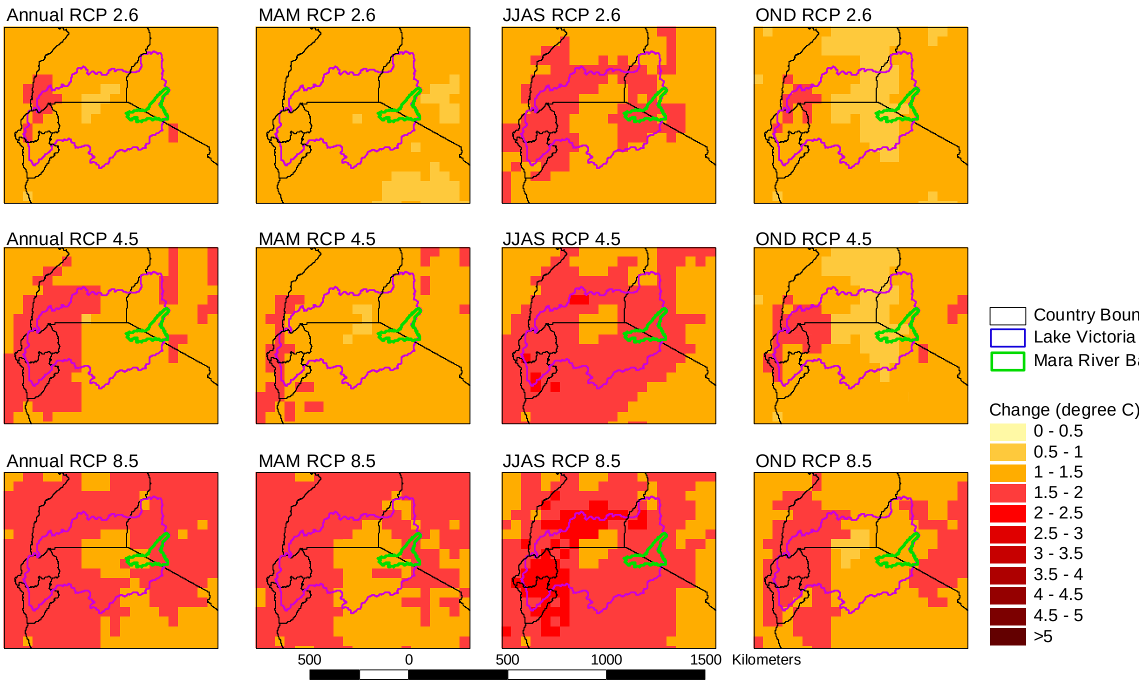
Figure 14: Mean projected temperature rise (°C) by season, time and scenario



Source: CCAFS Spatially Downscaled Data.
Note: Mean or change in monthly temperature compared with the reference period (1986–2005).
JJAS=June-July-August-September; MAM=March-April-May; OND=October-November-December

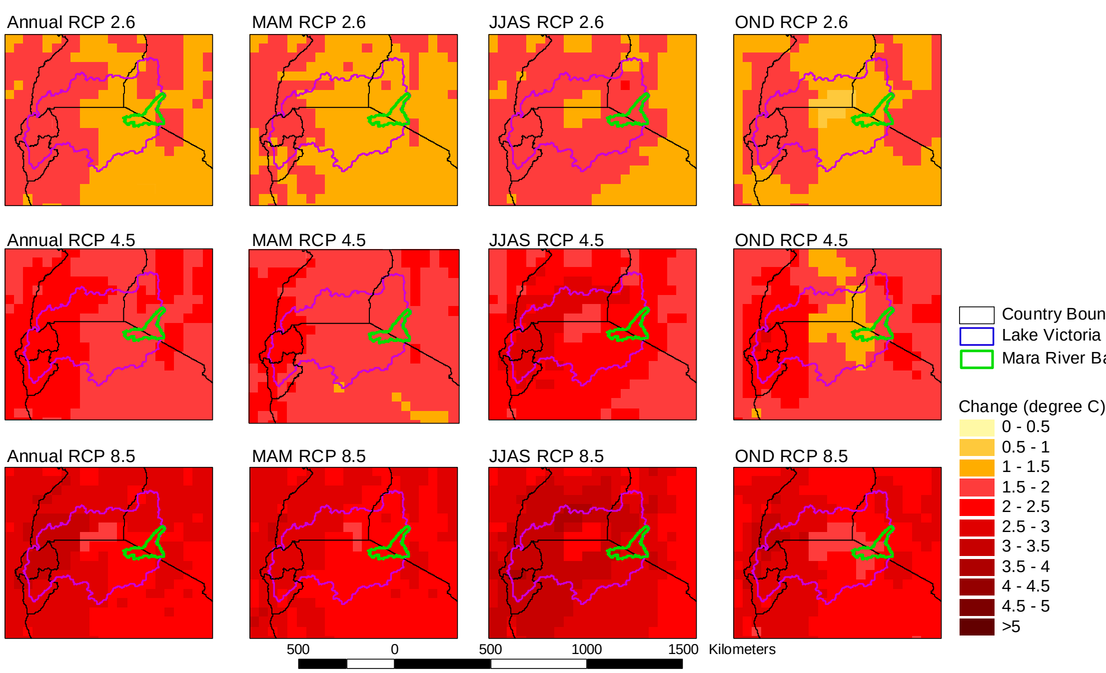
Projected minimum and maximum temperature varies significantly by season and scenario as shown in Figures 15 to 20 on the following pages.

Figure 15: Projected minimum temperature changes over the Lake Victoria Basin by the 2030s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)



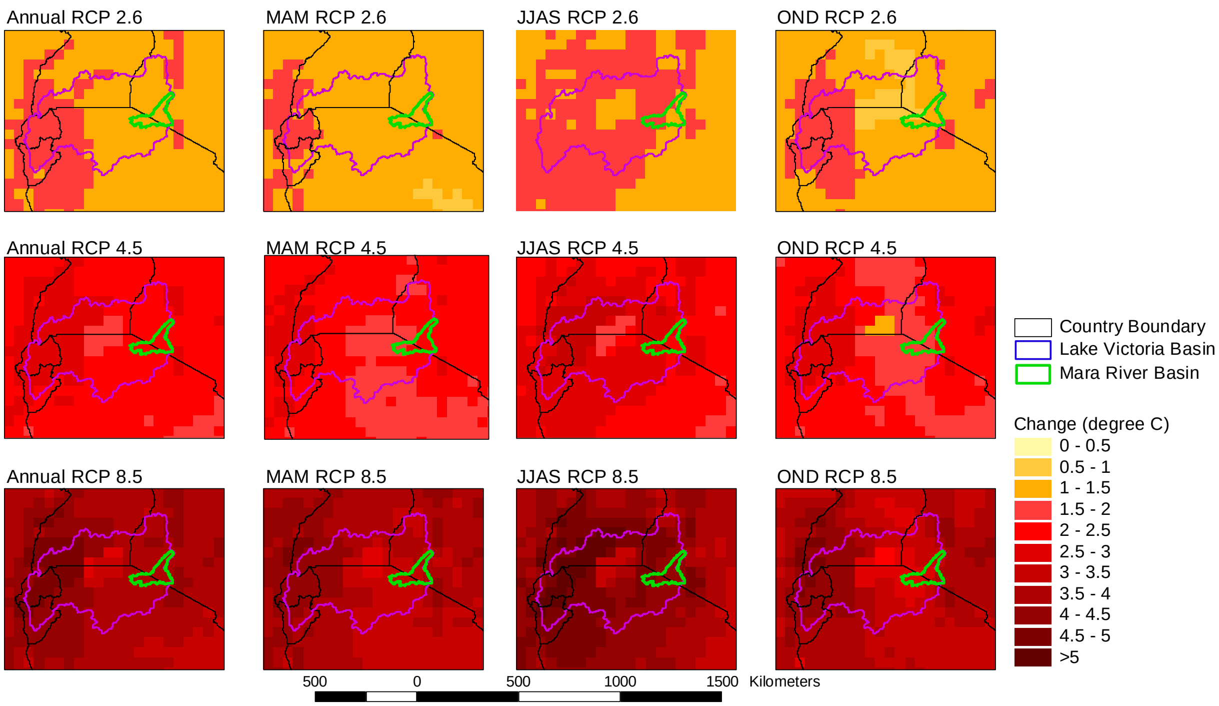
Note: Each row corresponds to an emission scenario.

Figure 16: Projected minimum temperature changes over the Lake Victoria Basin by the 2050s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)



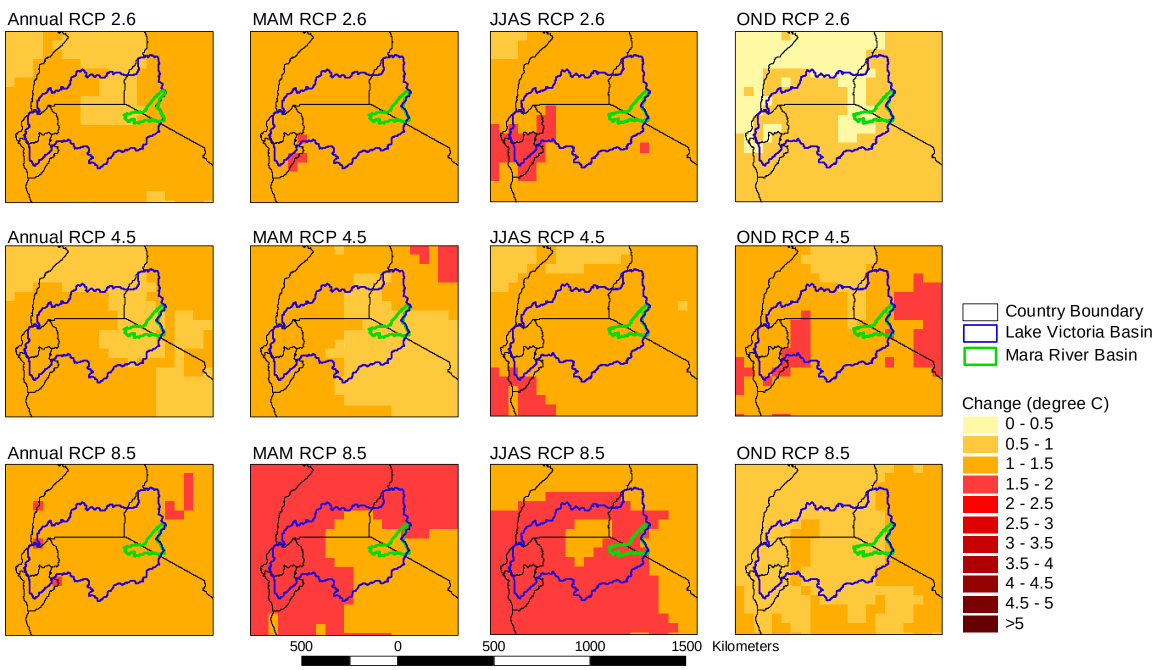
Note: Each row corresponds to an emission scenario.

Figure 17: Projected minimum temperature changes over the Lake Victoria Basin by the 2070s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)



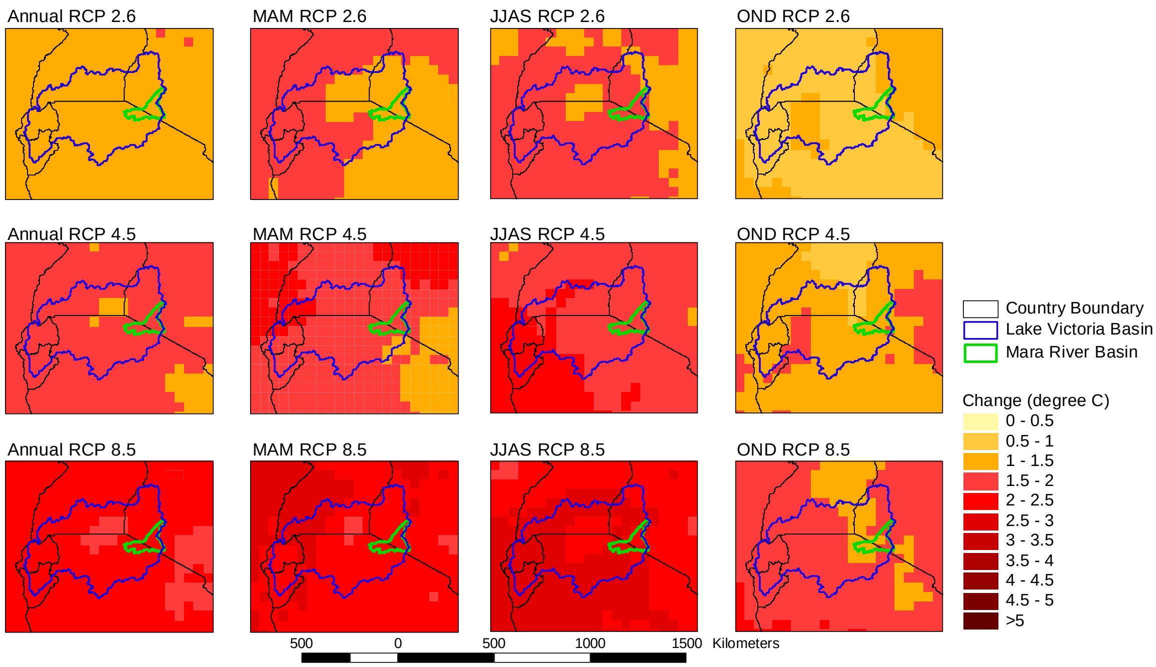
Note: Each row corresponds to an emission scenario.

Figure 18: Projected maximum temperature changes over the Lake Victoria Basin by the 2030s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)



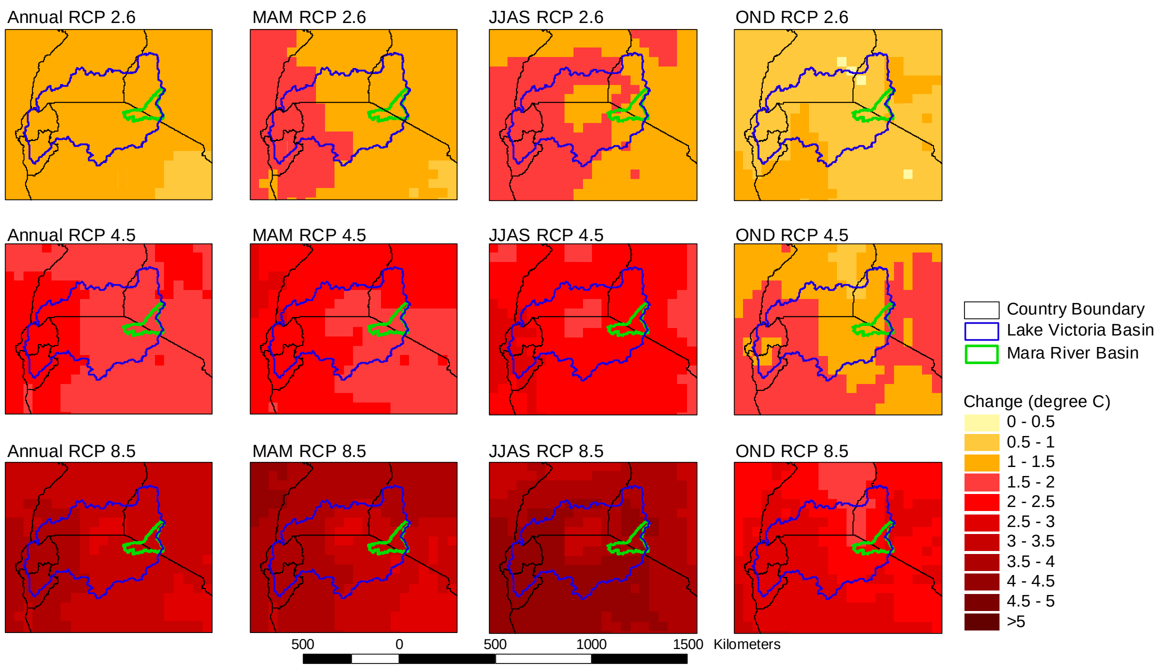
Note: Each row corresponds to an emission scenario.

Figure 19: Projected maximum temperature changes over the Lake Victoria Basin by the 2050s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)



Note: Each row corresponds to an emission scenario.

Figure 20: Projected maximum temperature changes over the Lake Victoria Basin by the 2070s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)

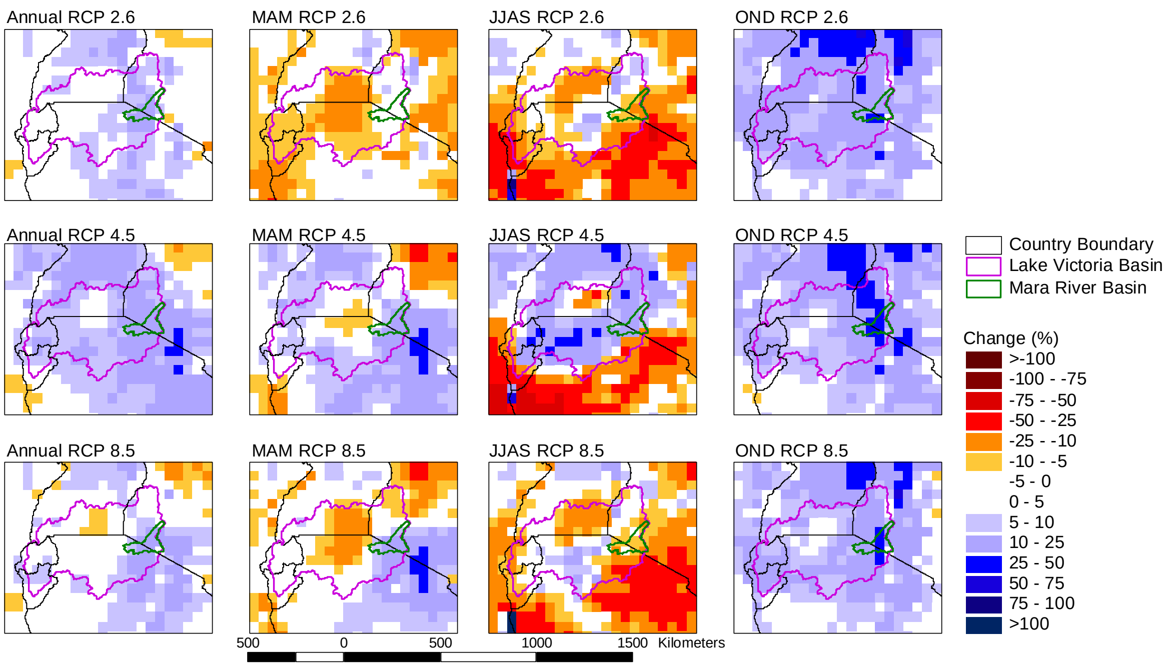


Note: Each row corresponds to an emission scenario.

Precipitation

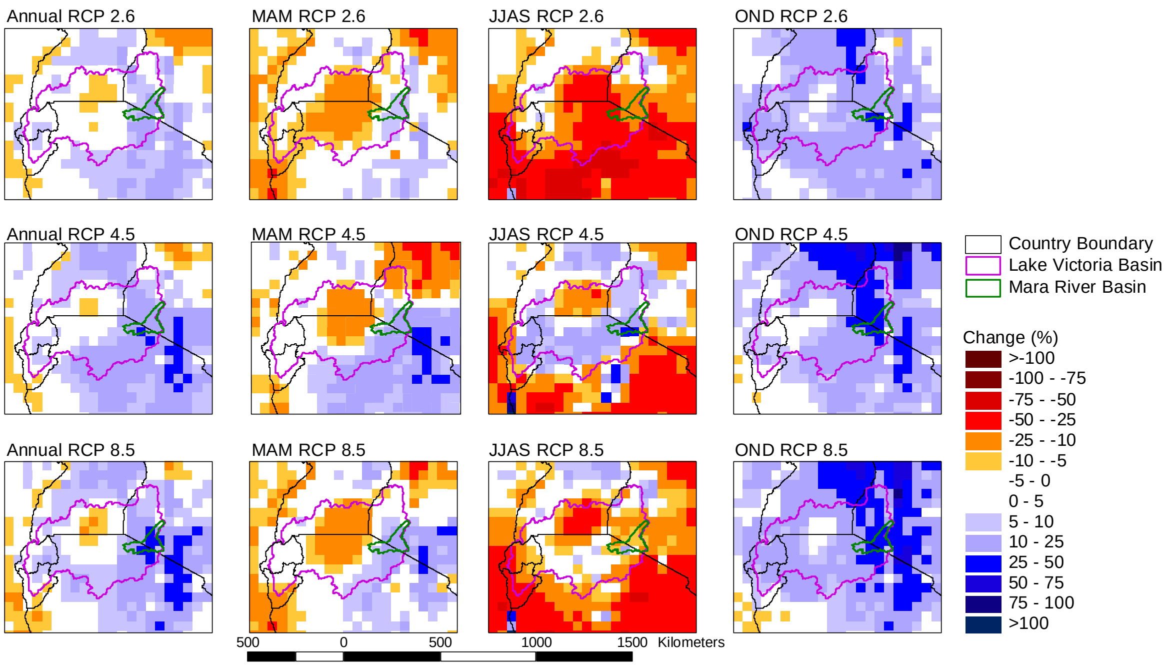
Precipitation projections are considerably less certain than for temperature with some models projecting drier conditions and others wetter (IPCC 2017), Nevertheless, the regional climate models all point to general wetting trend, with most models projecting increases in precipitation for both the short and long rains (Figures 21 to 23). This increase in precipitation is more pronounced during the short rains.

Figure 21: Projected rainfall changes over the Lake Victoria Basin by the 2030s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)



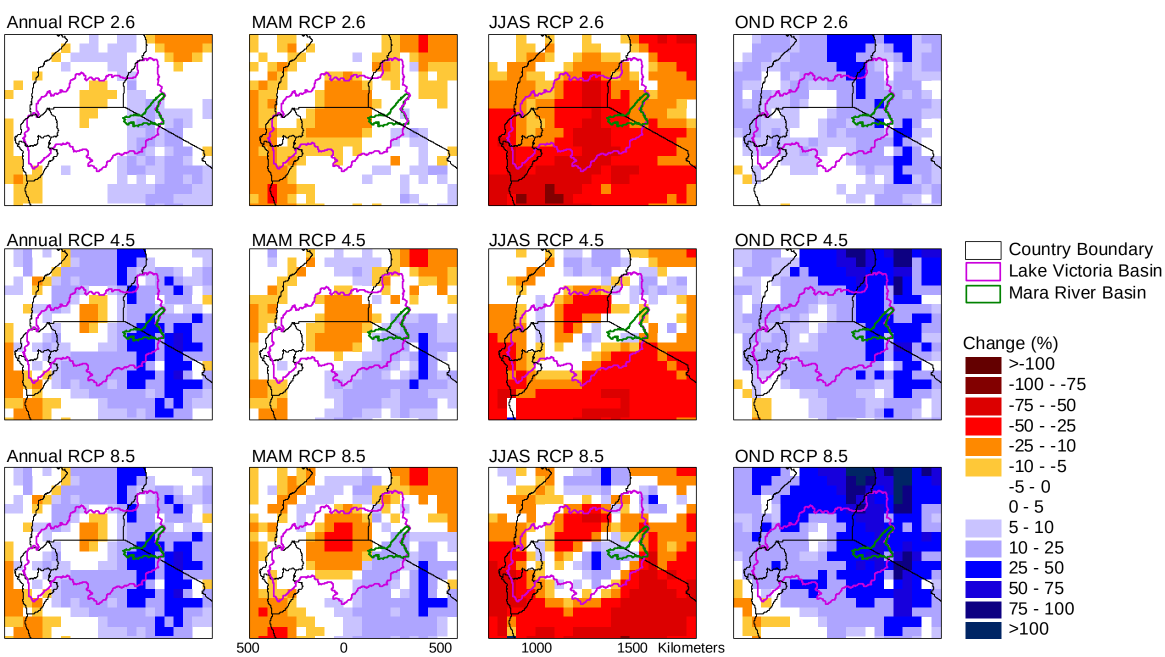
Note: Each row corresponds to an emission scenario.

Figure 22: Projected rainfall changes over the Lake Victoria Basin by the 2050s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)



Note: Each row corresponds to an emission scenario.

Figure 23: Projected rainfall changes over the Lake Victoria Basin by the 2070s annually and in the long rains (March-April-May), long dry season (June-July-August-September) and short rains (October-November-December)



Note: Each row corresponds to an emission scenario.

Seasonal patterns of change in rainfall and temperature

Changes in seasonal climate patterns add another level of complexity, and the differences between projections for the long and short rains are important for the MRB and the livelihood activities discussed in this report. Across all scenarios of change and all time periods, average temperatures increase during all seasons, but rainfall projections vary. At seasonal scales:

- Temperature increases may be more marked during the short rains and dry periods than during the long rains.
- The short rains period (October-November-December) is projected to have the greatest increase in precipitation, though some models also project a decrease (Figure 24).
- The long rains period (March-April-May) is projected to have minimal increases in rainfall, particularly with respect to the baseline rainfall values (Figure 25).

The seasonal changes are important for the livelihood activities discussed in this report.

Figure 24: Projected change values per 0.5º grid cell location within the basin, in temperature and rainfall during the short rains (OND) by 2050 for the Mara River Basin under RCP 4.5 and RCP 8.5

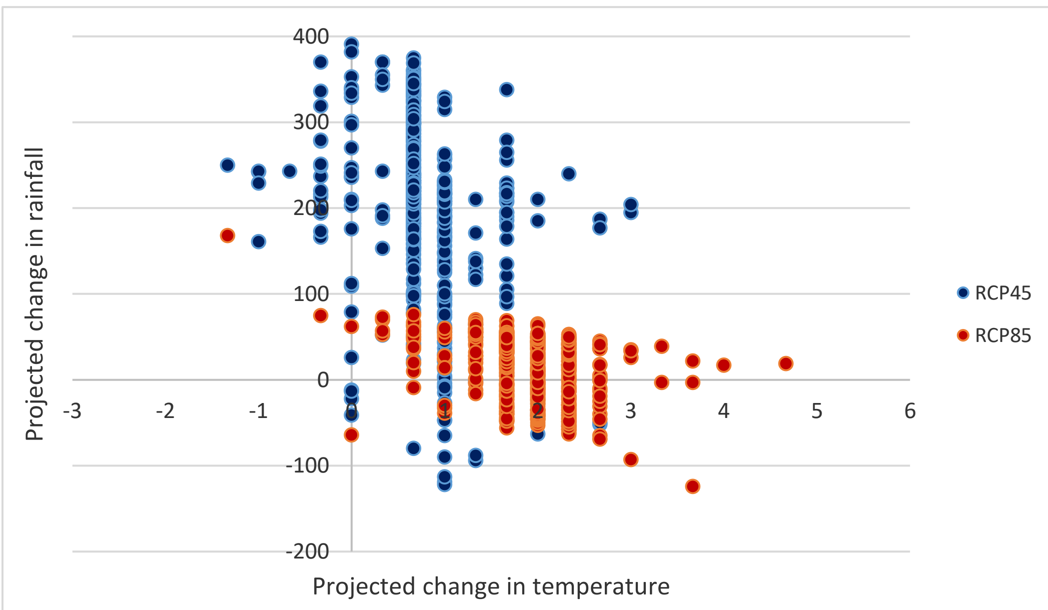
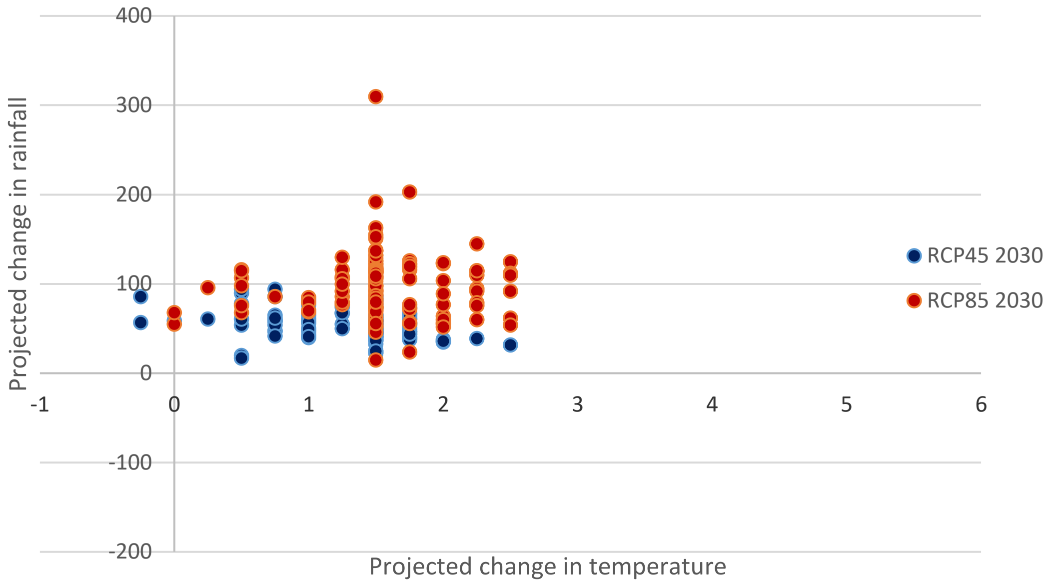


Figure 25: Projected change in temperature and rainfall per 0.5º grid cell location within the basin, during the long rains (MAM) by 2050 for the Mara River Basin under RCP 4.5 and RCP 8.5



Despite these projected long-term trends in both temperature and rainfall for the MRB, the year-to-year and decade-to-decade climatic variability will continue in the future as well. This means that a smooth upward trend in the short rains or in temperature will not occur; rather, this increase may not be evenly distributed and could instead result in episodes of extreme rainfall and extreme heat becoming more common. Temperature increases will nonetheless make warmer extremes warmer than previously observed and drier extremes drier, as soil moisture is reduced. Furthermore, as temperatures rise, increased evaporation will likely also lead to more intense rains.

OTHER PRESSURES IMPACTING CLIMATE SENSITIVITIES OF THE MARA RIVER BASIN

In climate analysis, sensitivity measures the propensity to be affected by a climate-induced event. It is in part a function of the current condition of the stakeholders and their livelihoods . For example, farmers reliant on rainfed agriculture are more sensitive to climate variability and change than people employed in urban areas. Variables examined under this category include: population, land use changes (as an indication of ecosystem integrity and potential changes in water requirements and flows), livestock and wildlife trends, and the overall livelihood mix of activities (see case studies) in each sub-catchment.

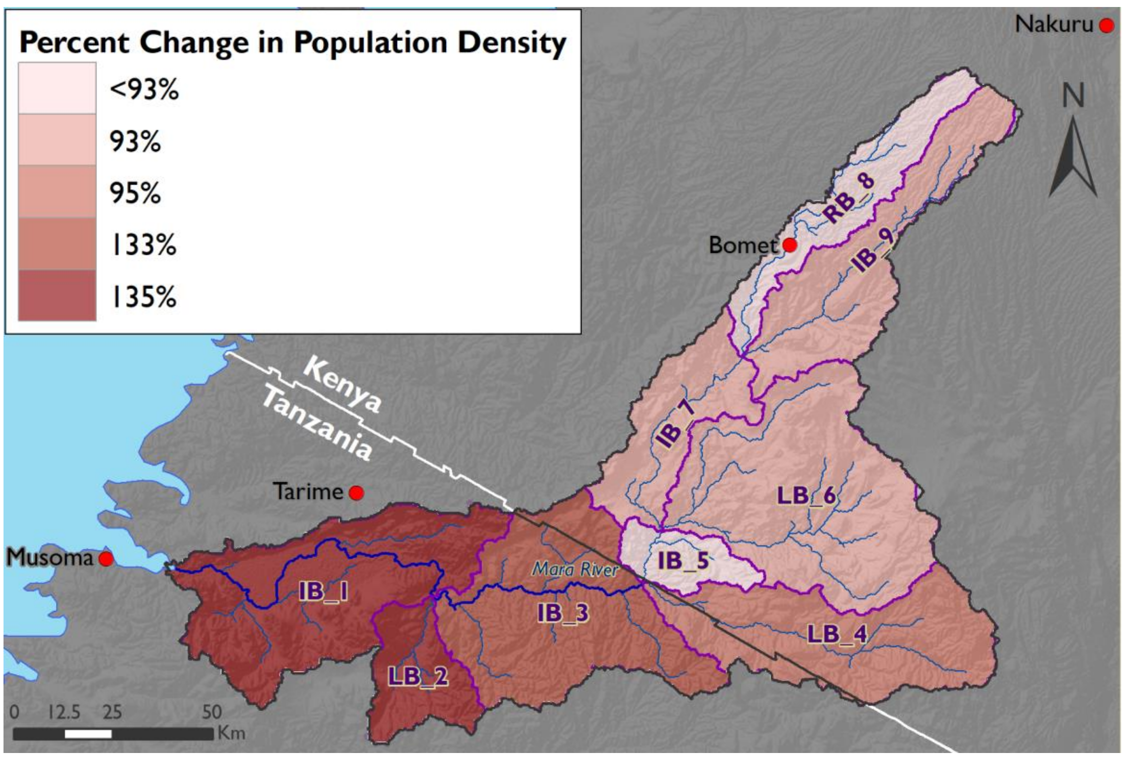
Population Dynamics in the Mara River Basin

The baseline population (referencing projections for 2018) shows that the greatest population numbers are located in the Amala, Nyangores and Mara Wetlands hydrological units. The lowest current numbers in those units are located in the eastern dryland basins and those corresponding to the wildlife corridors that encompass the Masai Mara and Serengeti national parks. The largest historical (2012–2018) population growth rates are within the Mara Wetlands and the hydrological units that are within Tanzania but outside of Serengeti National Park (Figure 26). Projections suggest that this will continue until 2030 (Figure 29) with the population in the MRB exceeding two million (Figure 28)

Looking at current population density (Figure 27), the Nyangores and Amala hydrological units (RB8 and IB9A) face the greatest pressures with 240 people per hectare, versus the lower population densities of approximately 130 persons per hectare in the lower reaches of the basin. This difference in population density is also projected to continue to 2030, with the exception of the Mara wetlands hydrological unit (IB_1), which is expected to reach densities similar to the Nyangores and Amala units. It is evident that as the upper and lower reaches of the basin face critical population thresholds, the hydrological units where the Serengeti and Masai Mara are located could begin to face additional pressures from a growing population caused by migration from other units that have been extended beyond their carrying capacity.

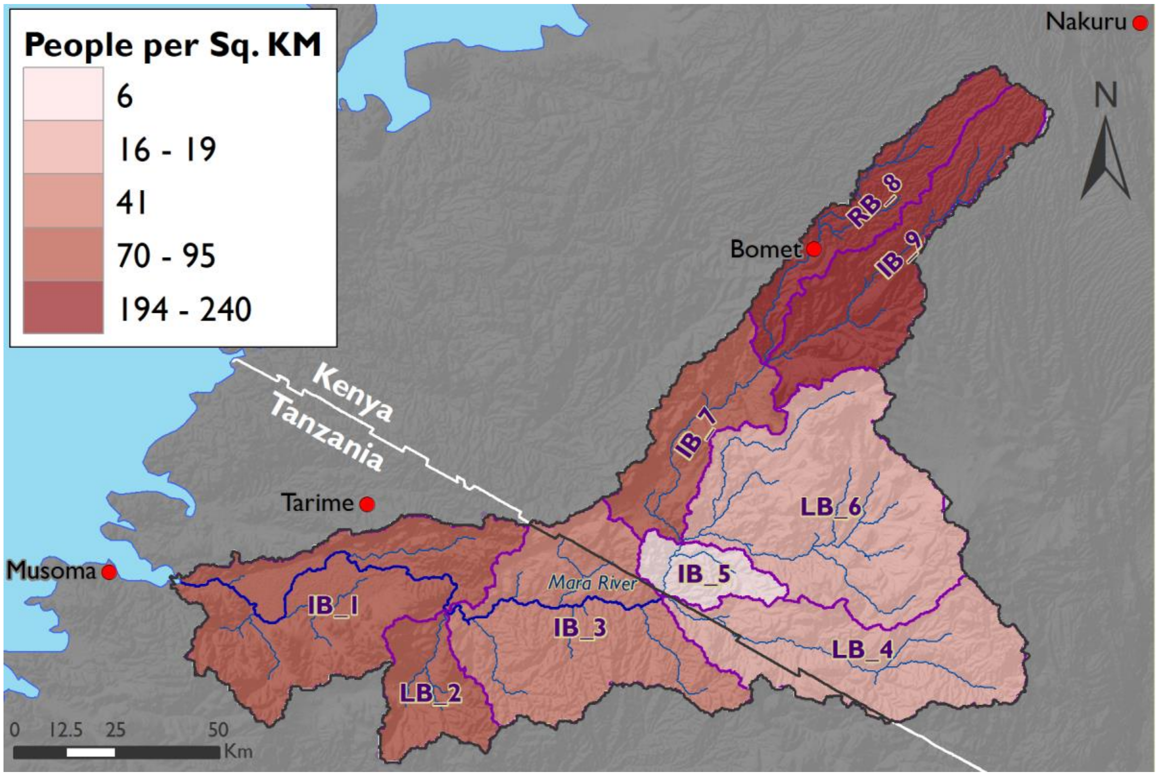
As these analyses suggest, there will be increased pressures on already limited land resources, particularly for farmers on the upper and lower reaches of the basin, who traditionally subdivide their land holdings to provide farming lands for their children. Already, these holdings are small, on average 1–2 acres, which will pose an increasing challenge for future populations, especially as densities are projected to increase.

Figure 26: Percent change in population density between 2012 and 2018 across the Mara River Basin by hydrological unit (sub-basin)



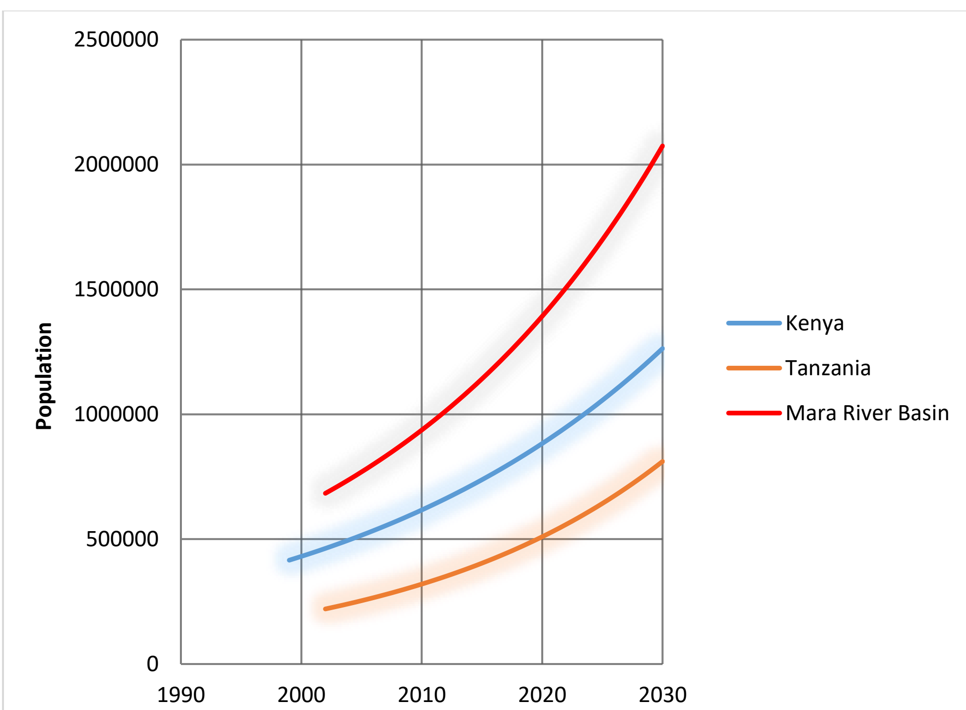
Source: Author’s calculations based on data description provided in the text.

Figure 27: Population density by hydrological unit in 2012



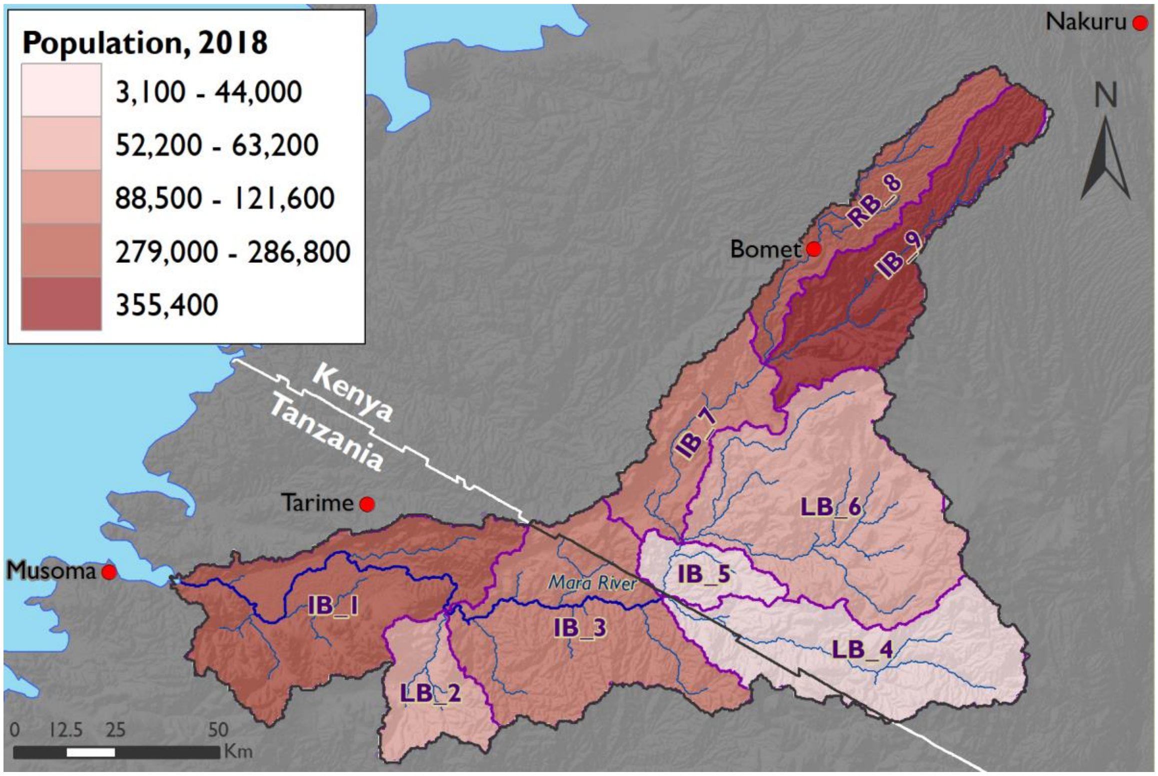
Source: Author's calculations based on data description provided in the text.

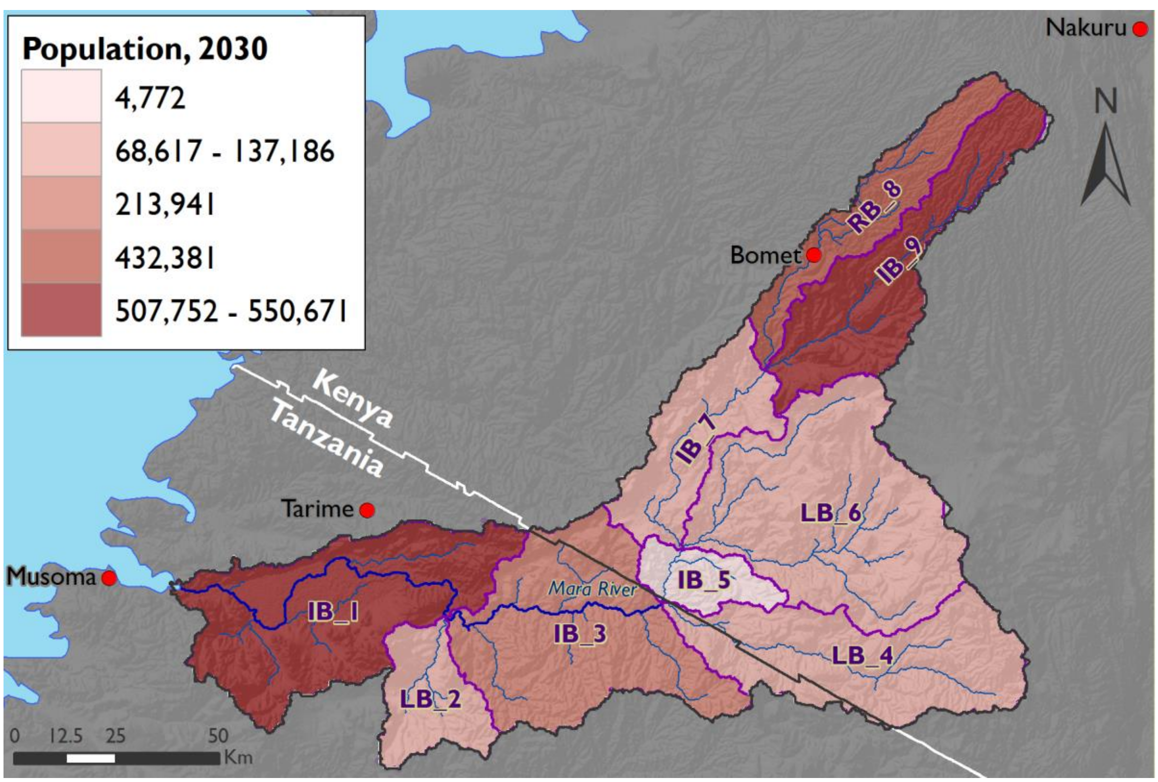
Figure 28: Population projections for the Mara River Basin and the Kenyan and Tanzanian areas of the basin



Source: Author's calculations based on data description provided in the text.

Figure 29: Spatial distribution of current (2018) and projected (2030) population by hydrological unit across the Mara River Basin





Source: Author's calculations based on data description provided in the text.

Land Use Dynamics in the Mara Basin

Forests in 1995 comprised 11 percent of the total land area of the basin, swamps less than 1 percent, shrublands 41 percent, grasslands 22 percent and agriculture 5 percent, with other categories covering less than one percent of the land area. The spatial distribution of these categories is presented in Figure 30, showing woodlands dominating the landscape in the Tanzanian portion of the basin, interspersed with grasslands and agriculture. Conversely, forests and agriculture comprise the majority of the land use in the upper reaches of the basin (the Nyangores and Amala rivers), home to the Mau forest complex. Encroachment into the forest and conversion to agriculture is visible already in the 1995 classification. Grass and shrublands dominate the landscape in the rangelands.

Figure 30: Land use, land cover and percentage of land area per class in the Mara River Basin in 1995

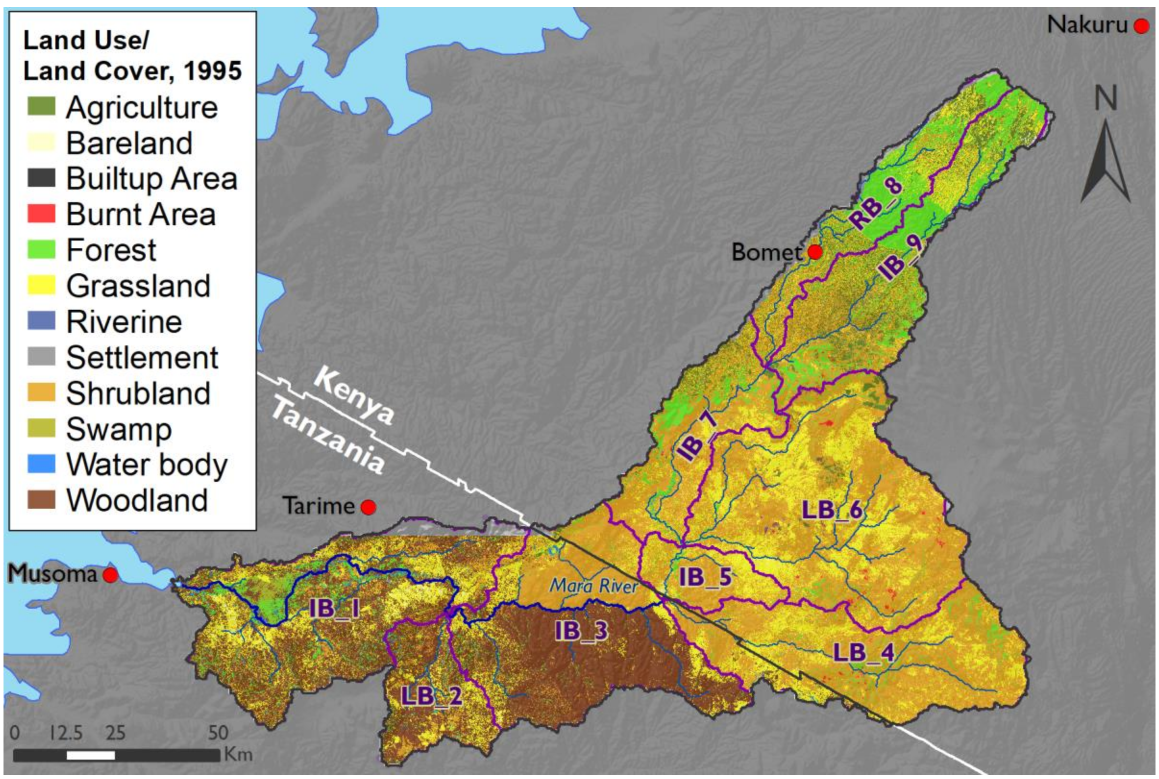


Figure 31: Land use, land cover and percentage of land area per class in the Mara River Basin in 2015

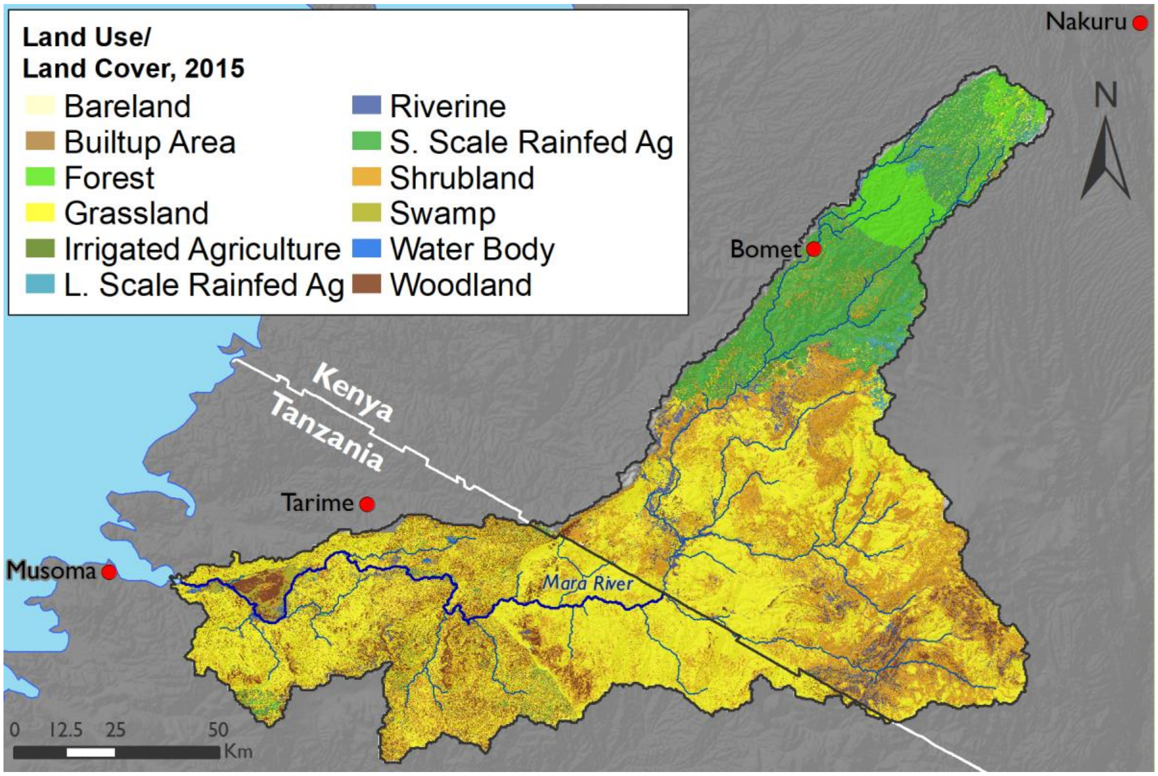
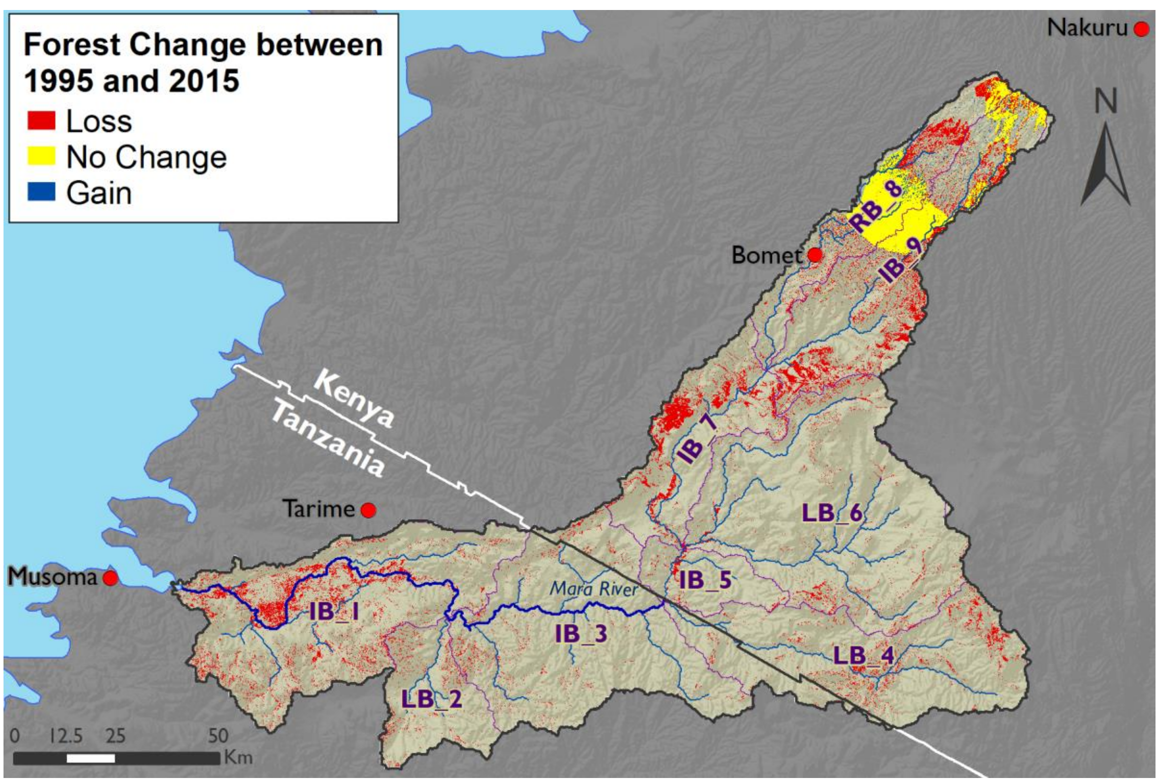


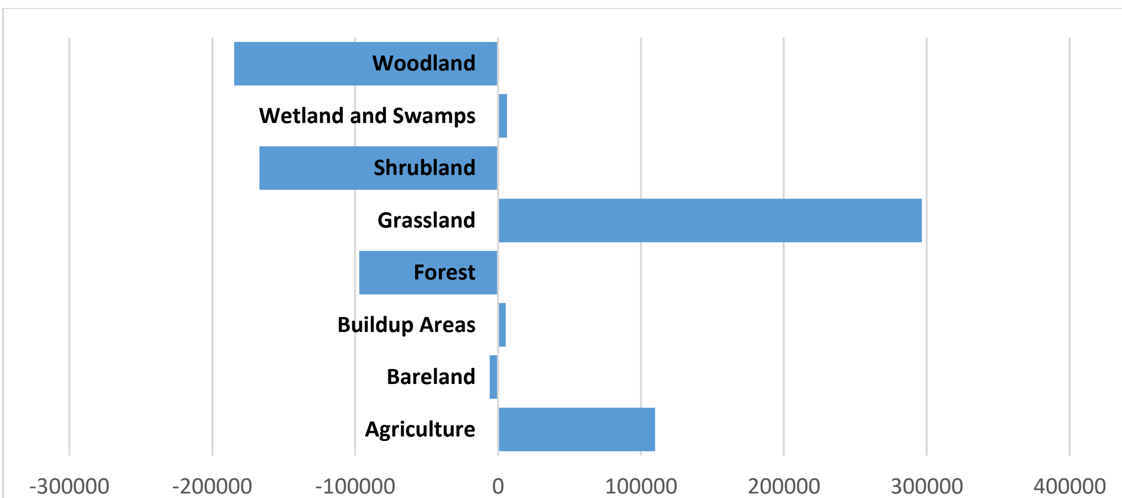
Figure 32: Forest cover change in the Mara River Basin between 1995 and 2015



The distribution of land use categories in 2015, as presented in Figure 31, begins to point to the changes that are already taking place across the basin:

- Agricultural expansion and intensification from the conversion of forests, woodlands, and shrublands to agriculture (Figure 33). While this is occurring throughout the basin, expansion and intensification are most marked in the upper reaches of the basin.
- Deforestation—Land conversion driven by a rapidly growing population and the need for cooking fuel are putting increasing pressure on the basin's forests, which have continued to decline (Figure 32). A preponderance of the population use firewood or charcoal as their primary fuel source for cooking, many turning to illegal logging and firewood harvesting, particularly during droughts. Deforestation can increase soil erosion and sedimentation of critical streams and tributaries to the basin. Deforestation can also lead to land degradation, though there is limited information on these dynamics in the Mara basin.
- Conversion of shrublands and woodlands to agriculture and grazing areas (grasslands).
- Increase in swamp area corresponding to additional sediment loads noted in the Mara Wetlands.
- Small but significant increases in the land area allocated to settlements (not shown in figure due to scale of changes relative to others).

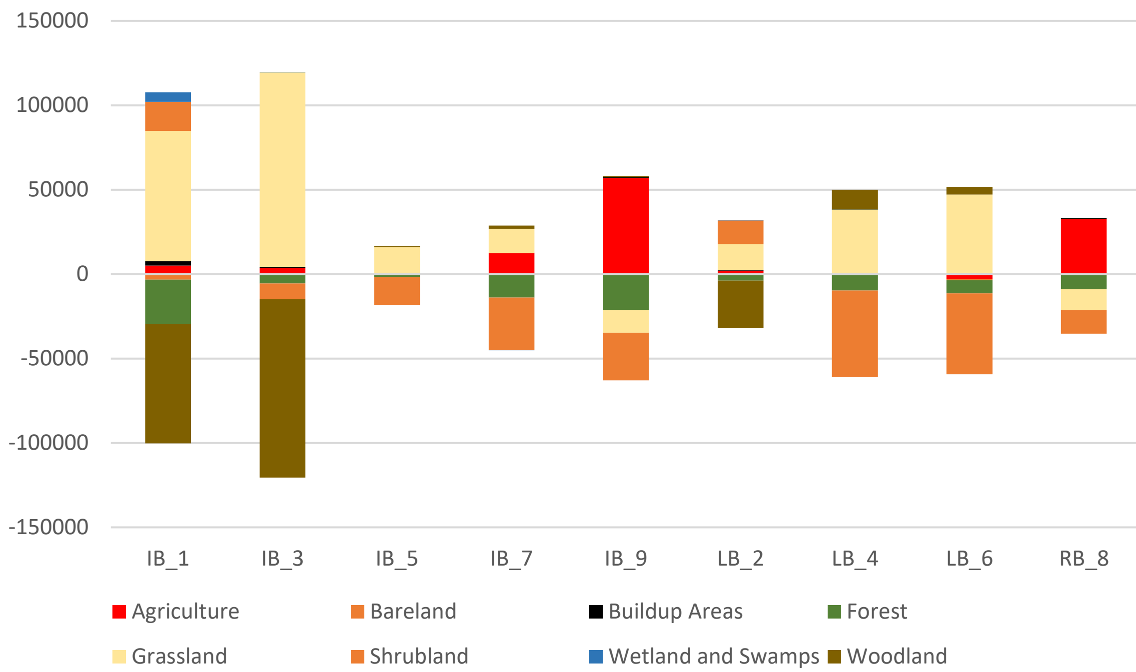
Figure 33: Overall land use changes in hectares across the Mara River Basin between 1995 and 2015



At the scale of hydrological units (refer to Figure 1, page 7), key insights from the land use and land cover change analysis are summarized in Figure 34. These include:

- Largest reduction in forest area is in the Mara Wetlands
- Reduction of woodlands in Tanzania with very slight increases in other hydrological units
- Increase in agriculture across the basin, with the most marked area increases in the Nyangores (RB_8), Amala (IB_9) and upper Mara (IB_7)
- Shrubland reduction across most of the basin, with the exception of increases in IB_1 and LB_2 the Sumuji

Figure 34: Land use changes in hectares by hydrological unit between 1995 and 2015



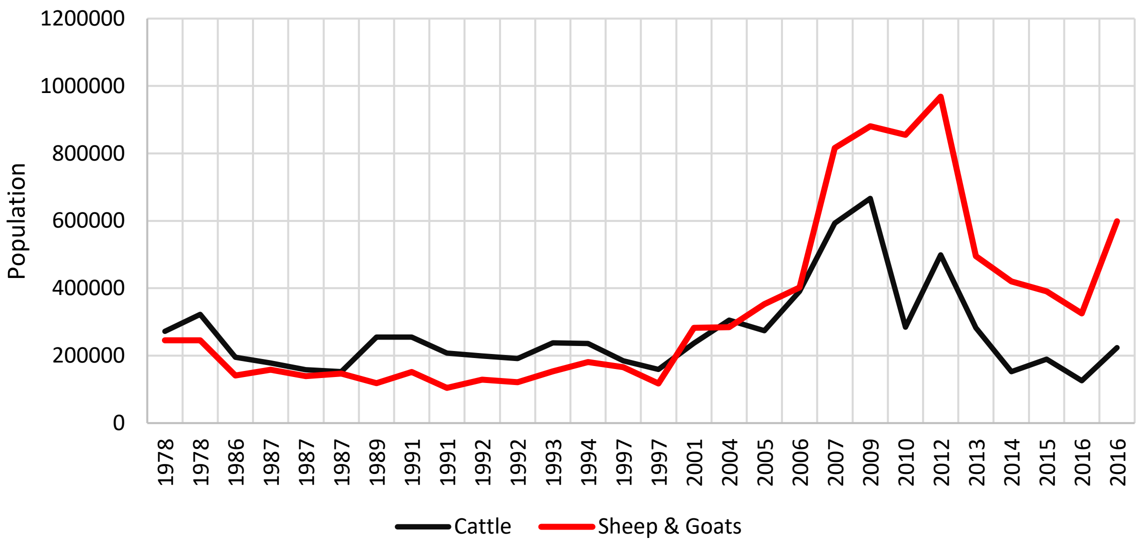
Livestock and Wildlife Trends

Livestock rearing, both for meat and milk, is a lucrative though challenging economic activity across the basin. Production practices vary from small-scale, free grazing on unimproved pastures or stall-fed production of beef and milk cattle in the upper reaches of the basin, to open range, traditional pastoral rearing in the rangelands. Most of the cattle in the basin are local breeds, which are more resilient to changing climatic conditions than imported breeds. Sheep and goats, while traditionally reared in the MRB, are gaining prominence due to increasing pressure on population, fencing, land privatization and the carrying capacity of the basin's ecosystems, which has limited traditional migratory corridors and available lands (see below). Aerial counts of livestock production in the pastoral open range between 1977 and 2016 by the Directorate of Resource Surveys and Remote Sensing (see details of the methods in Norton-Griffiths [1978] and Ogutu et al. [2016]) show that in the earlier periods there were more cattle than sheep and goats, and the numbers were low. However, in the 1990s—which were punctuated by periods of significant drought and fluctuating productivity—the number of cattle, sheep and goats decreased.

During the period between 2006 and 2012, the population of sheep and goats exceeded 800,000 in the Mara River Basin pastoral areas (Figure 35). The peak livestock population was in 2008, when more than 1.55 million livestock were counted in the pastoral area of the basin. Between 2009 and 2016, the number of cattle declined significantly, and the number of sheep and goats declined moderately (Figure 35). However, during the last count of the area in 2016, observers recorded an increase to 600,000 sheep and goats. The case study in the Nyangores sub-catchment (Annex 1) found that stall-based dairy goat farming is a rapidly growing activity, in part because it requires limited land, capital investment and labor and offers secure income and nutrition for small landholders. Goats are also well adapted to the climate challenges facing farmers in the Nyangores sub-catchment, including extremely dry conditions, and can graze on fodder from locally adapted species such as *Calliandra calothyrsus*.

The highest densities of livestock with respect to available land area are found in the Talek sub-catchment (LB_6), and the increase in livestock production corresponds to the reduction in shrubland in the sub-catchment.

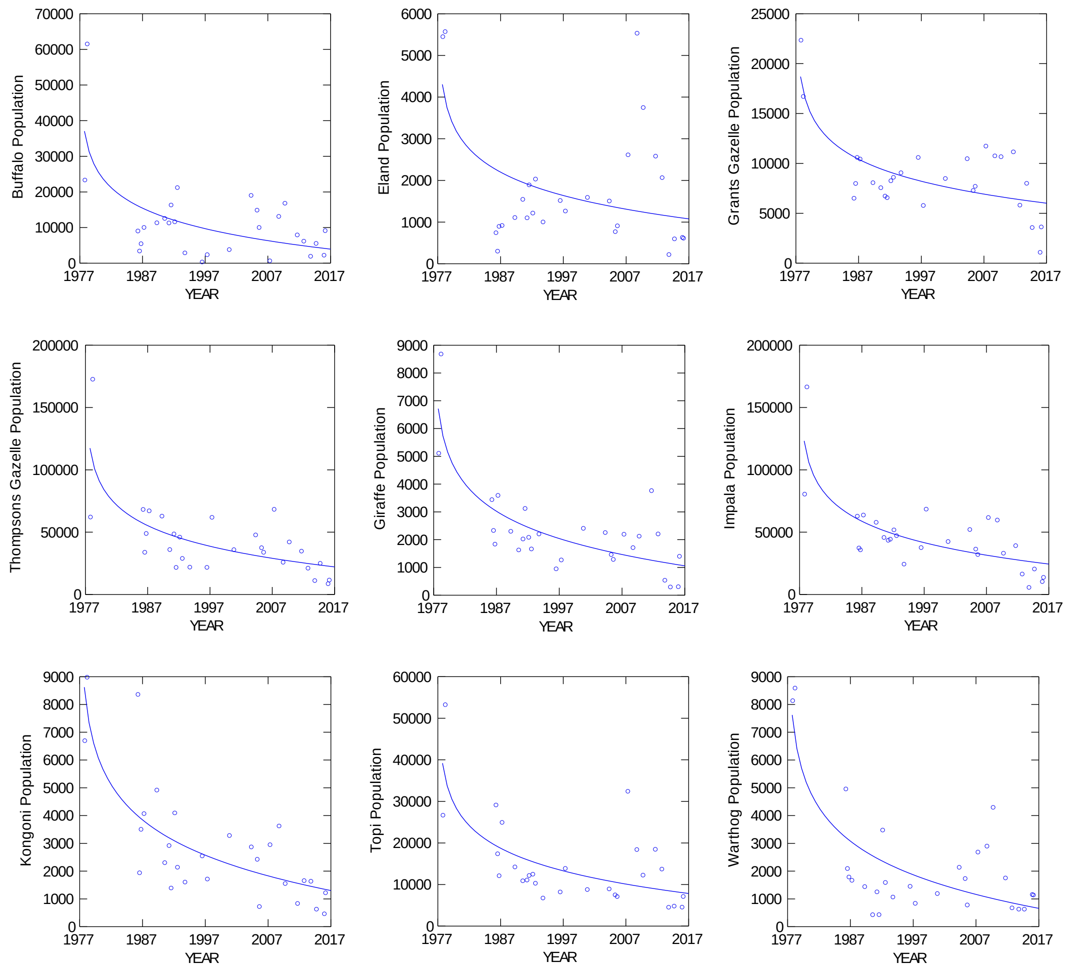
Figure 35: Livestock trends across the basin from 1978 to 2016



Wildlife and livestock have lived side-by-side across the Serengeti-Mara ecosystem for over 2,000 years. The two iconic parks, the Serengeti National Park in Tanzania and Maasai Mara National Reserve in Kenya, are famous for wildebeest migration. The migration in this ecosystem is the most extensively documented and involves about 1.3 million wildebeest (*Connochaetes taurinus*), 0.2 million zebra (*Equus quagga burchelli*) and 0.4 million Thomson's gazelle (*Gazella thomsonii*) (Thirgood et al*.* 2004).

Nevertheless, the marked recent changes in land tenure, land management (including fencing), population (3 percent growth rate in Kenya and 4 percent in Tanzania), land use, illegal hunting for bush meat and climate change now jeopardize not only this coexistence, but also the tourism revenue on which both countries rely. Aerial census data from the Directorate of Resource Surveys and Remote Sensing (see Norton-Griffiths [1978] and Ogutu et al., [2006]) indicate wildlife numbers are declining across Kenya, as shown in Figure 36. This is a consequence of the combined effects of these pressures on the Kenyan side of the Serengeti-Mara ecosystem (Ogutu et al., 2016). Figure 36 shows the trends between 1977 and 2016 of the individual wildlife species that are found on the Kenya side of the Mara River Basin. The trends indicate that among the 15 resident species, 13 had high rates of decline, and only elephant and ostrich populations increased between 1997 and 2016, the former due to increased protection efforts. The migratory wildebeest increased between 1986 and 2012 and declined slightly between 2012 and 2016, with a peak population of approximately 500,000. The population of zebra has declined significantly and as of 2016, stands at 35,000.

Figure 36: Wildlife population trends on the Kenya side of the Mara River Basin between 1977 and 2016



SUMMARY

This assessment demonstrates robust evidence for increased temperatures, extreme weather events and changes in rainfall patterns across the MRB, together with evidence that some of these changes have already begun. In response, the users and the underlying water allocation plan must include adaptation strategies to become more resilient to these changes. However, it is also important to note that climate is only one of many challenges facing the basin. Indeed, as shown across this report, these changes often confound existing livelihood problems, such as limited availability of land, a growing population, and land use changes that alter the ecological integrity of the critical ecosystems on which livelihoods depend. These risks as well as potential impacts are summarized in Table 7 below based on expert opinion across the basin.

While it is fairly certain that the basin's climate is already changing beyond the realm of recent historical variability, and will continue to change, it is impossible to project the future of climate risks exactly. Therefore, planning for a single future scenario is not recommended nor is a single set of investments—agricultural or institutional—as these cannot be effective across the board in the basin. In the end, it will be important to develop robust solutions that build national, community and individual resilience across all possible climate risks.

Table 7. Summary of climate stressors and climate risks by hydrological unit

	Hydrological Unit	Climate Stressors	Climate Risks
Upper	Nyangores, Amala	An increasingly unreliable rainy season poses a significant risk to already stretched traditional tea farming systems, a population highly reliant on wood for fuel and with varying access to quality water.	Prolonged dry periods, unreliable rainy periods and rising temperatures can: • Alter yields, or in extreme cases lead to crop failure, compromising food security and health • Increase the incidence of crop diseases such as fall army worm and maize lethal necrosis disease • Increase runoff rates as well as soil erosion and crop loss • Reduce soil moisture reserves • Increase the difficulty of maintaining healthy livestock in sanitary conditions • Reduce water availability and quality • Increase food insecurity and malnutrition • Increase the risk of vector- and waterborne diseases, including malaria and cholera • Increase the risk of waterborne illnesses and contamination of water sources • Reduce stream and river flows during critical dry periods • Increase pressures on critical ecosystems such as the Mau forest complex or springs • Increase milk spoilage due to higher average temperatures
Rangelands	Mara IB_7, Talek, Mara IB_5, Sand	Rising temperatures are critical, but water availability is mainly regulated by upstream users, which adaptation investments could address. As population pressures grow on the upper and lower reaches of the basin, and land management practices increase barriers to traditional wildlife migratory routes, the rangelands will continue to face considerable risks. This is especially important given the relative contribution of the parks within the rangelands to Kenya's and Tanzania's GDP.	Prolonged dry periods, unreliable rains and rising temperatures can: • Alter yields, or in extreme cases lead to crop failure, compromising food security and health • Alter or reduce water points critical for wildlife and tourism • Alter livestock and wildlife mortality • Decrease the quality of tourism experiences and revenue as wildlife move in search of water and food • Reduce water and natural pasture for cattle, threatening livelihoods • Increase overgrazing and damage riparian soil and vegetation • Reduce rangeland fertility • Increase the tensions between wildlife, pastoralists and park management, increasing the risk of incursion into wildlife sanctuaries
Lower	Mara IB_3, IB_1, and Sumuji	Rising temperatures and an altered rainy season are significant to livelihoods and will continue to put critical pressure on this region, pushing into the critical wetland ecosystem and jeopardizing livelihoods and species	Prolonged dry periods, unreliable rainy periods and rising temperatures can: • Reduce wetland resources, such as fish or thatch, or other plants that could be used for food in the dry seasons • Increase cropping pattern uncertainties • Reduce yield or quality of crops due to water stress • Increase crop damage through flooding, erosion and waterlogging • Decrease water quality and quantity • Reduce livestock reproduction, growth rates and milk production; increase morbidity and mortality • Increase the risk of vector- and waterborne diseases, including malaria and cholera • Increase food insecurity and malnutrition from decreased agricultural productivity • Reduce access to drinking water due to drying up of small streams and decreases in seasonal water

OPPORTUNITIES AND RECOMMENDATIONS

The evidence base identifying climate stressors, related climate impacts, nonclimate impacts and capacity for adaptation response must be considered when designing and implementing climate-resilience activities. Some current responses across the basin include investments in traditional livelihood diversification, alternative livelihoods such as growing higher-value crops (e.g., avocado, tree tomato) or raising milk goats, environmental conservation such as stream restoration and piloting for ecosystem services, and the untapped opportunity to invest in irrigation mechanisms to address dry season risks and rainy season shortfalls.

Table 8 on the following pages summarizes selected recommendations for the upper and lower reaches of the basin, encompassing the relevant hydrological units and grouped by the focus of the investment: governance, information, and pilot activities that include public sector engagement (priority actions for the rangelands should emerge from the study that is currently underway by the Sustainable Water Project). Many of the actions in the table were noted by communities as priorities, and some are articulated in the sub-catchment management plans, the WAP for Kenya, as well as the Mara Wetlands Integrated Management Plan in Tanzania. Recommendations are prioritized based on the authors' expert assessment of their urgency: immediate, medium term and longer term.

- Immediate recommendations address immediate needs based on current climate risks
- Medium-term recommendations offer high potential for buffering livelihoods to current and likely climate risks
- Longer-term recommendations focus on monitoring and research investments that can offer insights for interventions that are likely to occur in the next 10 years but are not yet critical.

Table 8. Selected adaptation responses

Adaptation Category	Summary	Action	Time Frame		
			Immediate	Medium Term	Long Term
UPPER: Nyangores and Amala					
Strengthening Governance	Revise sub-catchment management plan (SCMP) priorities to reflect experiences to date on effective adaptation strategies for	Develop costing concept note for stream restoration, including engineered stream designs such as those already employed to reduce siltation and guarantee flows through community involvement, and reforestation.	x		

Adaptation Category	Summary	Action	Time Frame		
			Immediate	Medium Term	Long Term
Strengthening Governance	livelihood needs and climate risks.	Write up case studies on alternative livelihood strategies highlighted by community members, including milk goat production, avocado, tree tomato and passion fruit. This should include information on both cost and methodology(engineering and technical know-how) guidance in order to articulate finance needs.	x		
		Share case studies with local government officials to offer the evidence base for seeking additional finance/support.	x		
	Strengthen WRUAs ability to promote climate-resilient practices	Build awareness of climate change issues across the WRUAs		x	
		Increase membership through awareness- building campaigns and add revenue streams to undertake additional monitoring and pilots		x	
	Restore pastoral migration rights of way	This requires either land tenure modifications or allowing removal of wildlife migration-inhibiting fences		x	
	Improve access to credit, insurance, and markets so that beneficiaries have options and safety nets in case of climate-related events.	Work either with existing insurance programs and markets to partner producer groups/beneficiaries or collaborate with financial and insurance companies to design products best-suited to the financial limitations of crop and livestock production.		x	
Improving Information	Invest in the dissemination of weather forecasts of relevance to local livelihoods	Work with the local meteorological office to define key variables affecting farmers and develop a method for disseminating this information to members of the local WRUA and CFA by radio and/or SMS.	x		
	Improve dissemination of information from crop and livestock early-warning systems as well as other forecasting and crisis preparedness systems.	Work with the Famine Early Warning Systems Network (FEWS NET) to ensure that beneficiaries are able to access this information easily in a format they can understand and act on to make better decisions.	x		
	Invest in improving the weather station network	In concert with the meteorological service, work to enhance the current weather observation network to increase the coverage of observations and monitoring sites for climate risks as they emerge			X
Piloting Interventions	Continue to invest in strategies undertaken by community members to improve livelihoods and build resilience to climate risks and other pressures	Invest in technical assistance to members of the CFA to safeguard investments and improve the viability of the production of new crops such as avocado, tree tomato and passion fruit.	x		

Adaptation Category	Summary	Action	Time Frame		
			Immediate	Medium Term	Long Term
		Continue to promote and finance soil and water conservation techniques, such as mulching and planting cover crops, to reduce sediment loads.	x		
		Continue to invest in stream restoration and sediment management based on a prioritized list of those at risk from the revised SCMP.	x		
		Develop projects to improve access to veterinary services for goat milk producers to address identified risks.		x	
LOWER: Mara IB_3, IB_1, and Sumuji					
Strengthening Governance	Finalize the SCMPs and prioritized list of adaptive actions	Incorporate considerations in the WAP for Kenya and Tanzania that specifically address how to improve water management to counter reduced water flows to catchment areas resulting from climate change.	x		
		Develop water abstraction regulations informed by the results of this vulnerability assessment and an environmental flow assessment for the wetlands.		x	
	Include the WUA members in water allocation planning	Incorporate the views and perspectives of the WUA members in water allocation plans and any negotiations related to harmonizing the Kenya and Tanzania WAP.		x	
	Strengthen WUAs' ability to promote climate-resilient practices	Increase membership campaigns and revenue streams to undertake additional monitoring and pilots.	x		
		Build awareness of climate change issues across the WRUAs.		x	
Improving Information	Promote the generation of information that could be used to design fit-for-location adaptation strategies or increase community awareness and participation	Increase membership campaigns and revenue streams to undertake additional monitoring and pilots.		x	
		Track and monitor sediment loads to the wetland, with the aim of informing adaptive strategies for upstream users.		x	
		Develop training and awareness materials and hold trainings and community meetings to enhance communication and capacity among Mara River Basin stakeholders to support proper conservation and management of the wetland as a transboundary resource.		x	

Adaptation Category	Summary	Action	Time Frame		
			Immediate	Medium Term	Long Term
		Improve data availability for the Mara Wetlands and adjacent areas, including regular biodiversity, social and demographic, and water level, quality and quantity surveys.		x	
		Repair existing hydro-meteorological data stations, reinstitute regular data collection, and increase number of data stations.		x	
Piloting Interventions	Invest in technical support for livestock producers and climate-smart agricultural practices to address the risks posed by a more variable climate	Invest in veterinary and crop extension services to address the increased risk to crops and livestock from diseases such as maize streak virus, cassava mosaic virus, Newcastle disease in chickens, foot-and-mouth disease in cloven-hoofed ruminants and *degedege* (convulsions) in sheep and goats.	x		
		Pilot small-scale irrigation schemes that could safeguard crop and livestock productivity during dry periods.		x	
		Introduce or scale up interventions to address deforestation by providing inputs (e.g., seedlings/saplings, soil amendments), equipment, training and extension services to enable on-farm agroforestry, and encourage use of improved cookstoves and alternative fuels.		x	
		Invest in sustainable production and management of livestock to address land degradation, including formulation and enforcement of by-laws regulating entry of cattle into ecologically sensitive areas, as well as support to farmers to access improved livestock breeds, employ reduced-impact feeding techniques and link up with new market opportunities.		x	
		Introduce interventions to address soil erosion, including soil rehabilitation, terracing along catchment slopes and training for extension workers on soil management technologies and techniques.	x		
		Invest in replanting and tree-based business opportunities to promote ecosystem restoration, including community woodlots, nurseries and seedling production, small-scale wood processing and fruit and fodder production.	x		

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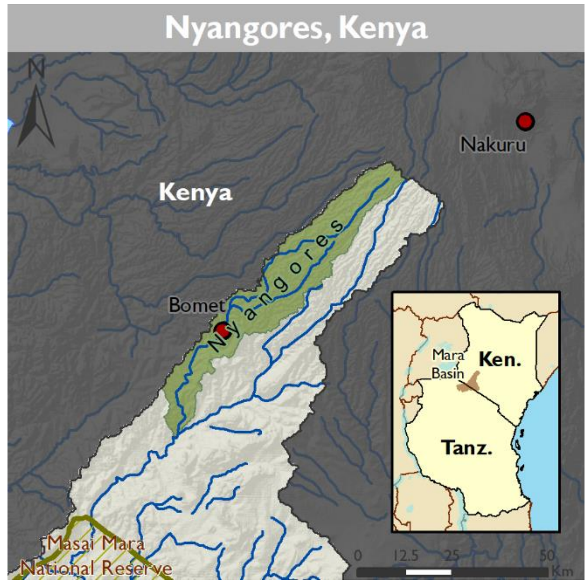
ANNEX 1: CASE STUDY – NYANGORES SUBCATCHMENT

SUBCATCHMENT OVERVIEW



The Nyangores subcatchment covers 902 km^2 in the highlands of Kenya's Southern Rift Valley region and sits at the northern boundary to the Mau Forest complex, the largest closed canopy forest in East Africa, and a critical source of water and other ecosystem services for the Mara River Basin. The catchment is situated within three very agriculturally productive counties in Kenya, endowed with vast areas of fertile land and abundant rainfall: Bomet, Nakuru and Narok. Despite the ample natural resources, poverty levels are significant and below the national poverty line (Bomet 48.8 percent, Nakuru 29.1 percent, Narok 22.6). Agriculture is the mainstay of the economy, focused on staple crops such as maize and sorghum, but also including large commercial tea farms and milk and livestock production. Significant land use changes, particularly the conversion of forests to agricultural land due to increased population pressures and need for land, place significant pressure on the region's inhabitants and resources. Climate variability and change are already affecting the subcatchment, increasing the incidence of vector-borne disease, particularly malaria, and leading to outbreaks of waterborne illnesses such as cholera and diarrheal disease. Crops and livestock, reliant on rains, are increasingly vulnerable, compromising food security and livelihoods.

CLIMATE PROJECTIONS

- 1.2/2.2°C increase in temperatures by 2020/2050
- More intense dry periods
- More variable rainfall
- Increased intensity of extreme weather events

KEY SECTORS AND VULNERABILITIES

Subsistence Crops
Reduced yields and yield losses
Crop stress and increased soil erosion
Food insecurity

Cash Crops
Reduced yield and yield losses
Income losses
Increased risk of frost

Livestock
Increased risk of diseases
Reduced productivity
Reduced water availability

Human Health
Increased risk of malaria
Undernutrition
Increased risk of waterborne disease

Water Resources
Damage to water infrastructure
Reduced access to safe drinking water

CONTEXT

The case study is aimed at organizations — including the Sustainable Water Partnership, as well as national and local governments, international donors, NGOs and community organizations — developing water use plans, policies and interventions in the case study geography, or within the broader Mara basin. The case study was designed to provide a highly localized vulnerability profile and recommendations for interventions, as well as provide local context for the vulnerability assessment of the Mara River Basin.

The information presented is based on desktop analysis and literature review as well as consultations held in Silibwet, Kenya on October 9, 2018, with 37 community members representing both the local Community Forest Organization (CFO) and the Water User's Association (WRUA). The participatory consultations included a series of exercises designed to understand local vulnerabilities to climate risks and identify the community's adaptive capacity to address these risks. Descriptions of the consultation exercises, along with community responses, are summarized in the case study but are also available in detail in Annex 4 of the USAID ATLAS project's assessment: *Vulnerability and Adaptation in the Mara River Basin*.

PRIORITY VULNERABILITIES AND KEY ACTIONS

WHAT MAKES THE COMMUNITIES OF THE NYANGORES SUBCATCHMENT VULNERABLE?

Deforestation primarily driven by high fertility rates which drive population growth and agricultural expansion. The areas that surround the Mau Forest, such as those in the Nyangores subcatchment, are hotspots of population growth and also favorable for agriculture, with their abundant rainfall and fertile soils [1]. As the region's population grows, so does the need to expand production beyond current plots. Population densities along the forest margins are well above the average for Kenya, with over 300 people per square kilometer. Agricultural expansion is primarily taking place through the conversion of forest lands to small-scale farming. Forest cover decreased in the Mara River Basin from 20 percent to approximately 7 percent between 1976 and 2014, with the majority of the decrease attributed to deforestation in the Mau Forest complex. Concurrently, small-scale agriculture increased from 6.5 percent of the landscape to 21.0 percent in the same period [2]. Additional forest encroachment is driven by firewood needs for cooking: 92 percent of households in Bomet and 80 percent in Narok rely exclusively on firewood [3].

Poverty and food insecurity. The majority of the subcatchment's inhabitants are poor, small-scale farmers who are vulnerable to the vagaries of markets and climate stressors, as they rely on seasonal rains for farming and water supply. Almost one-half (48.8 percent) live below the national poverty line in Bomet and 22.6 percent in Narok. Food insecurity is a critical issue in Bomet, particularly between January and April, when harvested stocks are generally depleted [4].

Increasingly unreliable growing seasons. The length of time that soil temperature and soil moisture conditions are suitable for cash and subsistence crops is changing, with delayed starts and more frequent failure of the short rains, making for less reliable growing seasons. Farmers now plant maize throughout the year, rather than relying on the historical long rains, which have become increasingly unreliable.

Increases in extreme events, including more intense rainfall events and longer dry periods. All crops grown in the Nyangores subcatchment are sensitive to rising temperatures, which can increase evaporation and reduce yields. Droughts and intense rainfall events also pose a risk to production.

COMMUNITY-IDENTIFIED VULNERABILITIES

In the upper Nyangores, drought and disease (both crop and livestock) were priority risks identified during the consultations, seen as having significant impacts on crops and livestock. Maize and potato were seen as the resources most at risk from climate change, respectively ranked “highly vulnerable” to droughts and disease and “moderately vulnerable” to land use change and flooding.

In the lower Nyangores, drought and flooding were the priority risks, seen as having significant impacts on most crops and livestock. Maize, beans and cattle were seen as the resources most as risk from climate change, ranked particularly vulnerable to drought, flooding and disease. These insights align well with the risks and vulnerabilities literature.

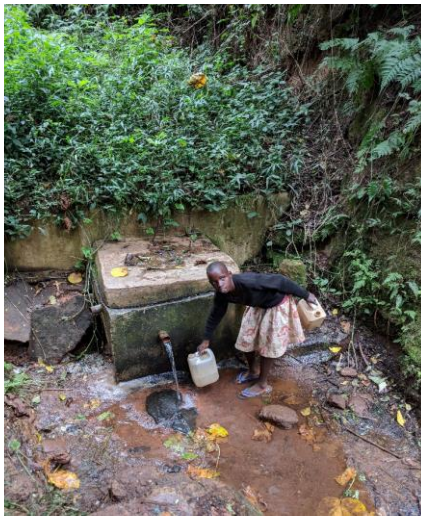
CRITICAL ACTIONS

The above-mentioned pressures notwithstanding, several opportunities to increase the resilience of the subcatchment inhabitants should be prioritized and supported. The activities listed below are grounded in the subcatchment management plans (SCMPs) for the area, and are already being implemented, with early results offering promising outcomes.

Alternative Livelihoods and Poverty Reduction

- *Avocado, Passion Fruit and Bananas* **–** Though tea production continues to dominate economic activities in the highlands, several farmers are now diversifying their existing plots to include the production of passion fruit, tree tomatoes and avocados, with some early success. Trial-and-error production is the norm, and extension services and support could boost productivity through climate-smart practices such as soil and water conservation measures, crop-residue mulching, grafting and sustainable land management practices.
- *Dairy Goats* – Stall-based dairy goat farming is an expanding alternative to livestock production, as it uses limited land and has the advantage of providing both a rapid source of income and a nutritional supplement for households [5]. Scaling up this activity will require a package of interventions aimed at addressing the challenges facing milk goat farmers, including a limited market for milk, timely vaccination and disease treatment, and limited extension services (particularly on value chain promotion and marketing) [6].

Examples of climate-resilient activities to prioritize in the subcatchment: home-based biogas digestor (left), restored spring (center) and avocado tree (right)


Resource Protection

- Several households are experimenting with *woodlots*, established with fast-growing, water-balanced native species, and the use of *home-based biogas digestors* to reduce deforestation and encroachment into the Mau Forest complex.
- *Rehabilitation of springs* – Springs, once silted, contaminated and nearly dry during critical months, now flow freely thanks to restoration efforts by the Nyangores WRUA. Restoration projects are designed and financed by the WRUA but implemented by local communities and include replacing eucalyptus with water-friendly species such as bamboo, the installation of sand filters, piping and access improvements. Fifty percent of the approximately 495 springs in the subcatchment are considered vulnerable and compromised, and only 22 have been restored to date. Providing financial support to continue the process is critical, as a single restored spring can offer clean water for 150 or more families, reducing pressure on the catchment.

Soil and Water Conservation Measures

- Soil and water conservation techniques, such as mulching and planting cover crops to reduce sediment loads, are actively promoted by the local WRUA. Lack of capital to purchase seed and limited technical support, however, continue to limit their widespread adoption. Several payment for ecosystem services (PES) pilots have been implemented, aimed at supporting farmers while reducing costs to users downstream. Scaling up these initiatives through public–private partnerships, could increase the resources available for these activities. For example, the private Tenwek hospital in Bomet invests over KSh 1 million each year to desilt storage of the Tenwek dam, which provides electricity to the hospital and nearby schools. A more sustainable option would be to support erosion control practices for farmers upstream, such as terracing and the use of cover crops along streams, who benefit from these activities by reducing the costs and/or frequency of siltation management.

CLIMATE SUMMARY

Average annual rainfall ranges between 1,000–1,400 mm, with the highlands of the Mau Forest complex receiving the greatest rainfall and rainfall decreasing toward the northeast. Two seasons are recognized: the wet season, which extends from March to December, and the dry season, which extends from January to February. The wet season is further characterized by the short rains (October–December) and the long rains (March–August). Average monthly temperatures range between 16–26°C; the coldest months occur between February and April when monthly mean minimum temperatures often drop below 16°C and the hottest between December and January.

HISTORICAL CLIMATE

Historical climate trends include:

- Increased average temperatures of 0.34°C per decade from 1985–2015
- Less reliable rainy seasons, with a total failure in some years of the short rains and an increase in the intensity of precipitation in others, altering the distribution of available water for agriculture
- More frequent frost and hailstorms[7]

FUTURE CLIMATE

Projected changes by the 2050s under RCP 4.5, indicative of the current evolution of climate to date and best-case scenario, include:

- An increase in average temperatures of 1.2ºC (by 2020) to 2.2ºC (by 2050)
- Increased interseasonal rainfall variability
- Increased duration (+9–30 days) of heat waves by 2050 under all scenarios of climate change.
- Increased frequency and intensity of heavy rainfall events

SECTOR IMPACTS AND VULNERABLBILITIES

AGRICULTURE

The subcatchment's agricultural production is already vulnerable to the vagaries of climate because crop production there is rainfed, with cropping cycles defined by the onset of the rains. Farmers typically lack capital inputs, finances and technical skills to use improved farming practices or agricultural inputs, which leaves them less resilient to the impacts of a changing climate. Practices to improve land preparation, such as terracing and crop rotation as well as the use of improved, certified seed, have been promoted. Adoption rates, however, remain low and in fact are reversing in some cases, as farmers are opting to plant lower-yielding traditional maize varieties or millet throughout the year rather than risking a loss to diseases such as maize lethal necrosis disease (MLND)[8], pests such as the fall armyworm[9] and/or droughts affecting the higher-yielding certified varieties. As one participant in a workshop conducted with farmers put it, "*Season-less periods are here*." In essence, farmers are changing their cultivation practices to a year-round, season-less climate. Without a major shift in farming systems, the situation for poor farmers is expected to worsen as the projections for climate change become reality. Nevertheless, farmers in the subcatchment are actively working to improve their resilience and several promising actions could be supported. These are described below for subsistence and cash crops.

Two broad topographical zones encompass the Mara River Basin, each with distinct agro-ecological characteristics, dominant livelihood activities and risks:

- *The upper Nyangores* – former forested areas with elevations ranging from 1,700–2,000 meters above sea level (m.a.s.l.). Small-scale tea farmers dominate this zone, which until recent years, enjoyed relatively stable weather conditions. Nevertheless, the recent occurrence of extreme weather events, including hail in 2012 that damaged 30 percent of the tea crop in Kenya,[10] extended droughts due to less consistent onset of the rainy season, and rising temperatures, coupled with reduced soil fertility and increased costs of requisite agricultural inputs, are beginning to alter the upper Nyangores agricultural landscape. Other crops, grown primarily for subsistence in kitchen gardens, include maize, potatoes, beans, kale and millet. Though tea production continues to dominate economic activities in the highlands, as the price of tea has fallen and production costs increased, some farmers are now diversifying what they cultivate on their land (typically 2–2.5 hectares) as previously discussed, with early results offering promising outcomes.
- *The lower Nyangores* – located at elevations of 1,600–1,700 m.a.s.l. in open woodlands and grasslands. Livestock and milk production dominate in this zone as a source of income, with many farmers planting Boma Rhodes (hay) to feed their cattle. Subsistence crops, which are also sold locally in farm stands, include sweet potatoes, maize, onions, beans, sorghum and millet. As droughts have intensified, banana production has increased, both as a food crop and a cash crop.

Barriers to community uptake of adaptation actions (including those listed below) include: lack of capital to invest in new techniques and technologies; lack of access to improved inputs; lack of awareness of options and training on new techniques; and a low tolerance for risk. Any successful intervention will need to be designed to take these barriers into account.

Subsistence crops

Most of the subcatchment's inhabitants practice subsistence farming in small kitchen garden plots, and these account for the bulk of household nutrition. All crops are rainfed and highly sensitive to changes in both temperature and rainfall, though in varying degrees. Prolonged dry periods, unreliable rainy periods and rising temperatures can alter yields, or in extreme cases lead to crop failure, compromising food security and health. Droughts, previously occurring every 10 years, now occur every 2 to 3 years in the Nyangores, with farmers noting the years 1999–2000, 2004 and 2016–2017 as the most severe. The 2016–2017 drought, which affected most of the country, placed more than 2 million people in need of food aid and tripled the price of maize on the market, further compromising the food security of subcatchment inhabitants [11].

Climate Stressors and Climate Risks AGRICULTURE – Subsistence Crops		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures **Increased evaporation** **Increased rainfall variability** **Extreme weather events (drought, hail and frost)**	Reduced yields or crop failure	• Purchase of certified seeds, irrigation, alteration of cropping cycle
	Altered seasonal boundaries and growing days available	• Change in planting patterns, such as altering rotations, using intercropping to reduce soil moisture loss, mulching
	Wildfires	• Irrigation
	Increased runoff rates as well as soil erosion and crop loss	• Application of fertilizer
	Rising number and incidence of crop diseases such as fall army worm and maize lethal necrosis disease[12]	• Use of pesticides, crop rotation, hybrid seeds

Cash crops

The rich soils and until recent years, abundant and reliable rainfall of the subcatchment, combined with optimal elevations of 1,500–2,100 m.a.s.l. made for ideal conditions for tea production in the upper reaches of the subcatchment. Indeed, tea continues to be a dominant economic activity, with farmers allocating a between 70 to 90 percent of their plots to the crop. However, recent changes in temperatures, and the more frequent occurrence of frost and hailstorms [7], especially when coupled with the lower market value of tea, have reduced yields and challenged the profitability of tea production. In January 2012 alone, 30 percent losses of green leaves were recorded in nearby Kericho due to frostbite. Furthermore, these cold temperatures limit workers' productivity, reducing daily yields for farmers. Temperature variability has the greatest impact on yields, particularly during the dry spells. A warm, wet season is ideal for production, but these are becoming rarer as rains become more erratic. Recent studies suggest a projected shift upward in altitude for tea production, to 2,000–2,300 m.a.s.l., due to rising temperatures.

As noted previously, although tea production continues to dominate economic activities in the highlands, several farmers are now diversifying to include the production of passion fruit, tree tomatoes and avocados. Passion fruit, for example, faces a ready and eager market and the Kenya Agricultural and Livestock Research Organization's (KALRO) new drought-tolerant varieties offer resilience in the face of changing rainfall patterns. With proper management, which includes regular weeding, foliar feed application and spraying against whiteflies (the most common pest), passion fruit production can significantly increase incomes.

Since 2014, Hass avocados, another high-demand crop alternative to tea, have provided better earnings to many farmers in the region and are a healthy source of nutrition for local families. A properly watered two-year-old tree can provide 1,000 avocados, which more than doubles the income farmers receive from a half hectare of tea. Challenges remain, however, particularly with regard to seedling survival. Of the 14,000 trees originally planted in the highlands, only 50 percent survived due to lack of technical knowledge in successful agronomic practices to safeguard seedling survival, and seedling costs can be prohibitive, as grafting skills are poorly developed. Nevertheless, with proper extension support to address these issues, and initial finance to invest in new trees, the avocado market offers promise to poor farmers.

As with avocado in the highlands, bananas grown along the river banks, which are seasonally inundated in the lower Nyangores, offer resilience and nutrition against the vagaries of increasingly "season-less" years. Trial-and-error production is the norm, and financial and technical support could boost banana productivity through climate-smart practices such as soil and water conservation measures, crop-residue mulching and sustainable land management practices.

<table>
<tr><th colspan="3">Climate Stressors and Climate Risks
AGRICULTURE – Cash Crops</th></tr>
<tr><th>Stressors</th><th>Risks</th><th>Illustrative Adaptation strategies</th></tr>
<tr><td rowspan="4">Rising temperatures

Increased evaporation

Increased rainfall variability

Extreme weather events (drought, hail and frost)</td><td>Yield losses</td><td>• Mulching, terracing, pruning of tea crops</td></tr>
<tr><td>Crop failure</td><td>• On-farm diversification using viable alternatives such as avocado, banana, passionfruit and tree tomato</td></tr>
<tr><td>Soil erosion</td><td>• Terracing and mulching of tea plantations</td></tr>
<tr><td>Reduced soil moisture</td><td>• Mulching, use of leguminous cover crops</td></tr>
</table>

LIVESTOCK

Livestock farming is a lucrative though challenging economic activity, contributing 10 percent to the overall economy of Narok county alone. Cattle are also traditionally a form of savings for families. Small-scale, stall-fed livestock production of beef cattle is common across the Nyangores subcatchment, with farmers owning 1–2 cattle on land cropped with any combination of tea, maize, some fodder and kitchen gardens. The majority of these are local breeds, which are more resilient than imported breeds to changing climatic conditions but also highly vulnerable to diseases such as foot-and-mouth disease.

Milk production

Small-scale dairy production is a large subsector in the Nyangores. A variety of milk production systems are employed by the largely smallholder farmers, who own 1–2 animals, reflecting the realities of high population density and limited land availability. The most common are small-scale, free-grazing on unimproved natural pastures, complemented in some cases with small-scale Napier grass (*Pennisetum purpureum*) planting. Stall-fed systems that supplement grass feeding with concentrate feed are rare. Constraints for dairy farmers include inadequate quantity and quality of feed, limited use of improved cattle breeds as well as the high cost of artificial insemination, lack of improved animal husbandry and farming practices, and poor infrastructure, leading to reduced market values. Additionally, milk production is affected by strong seasonality, particularly with regard to rainfall, with sharp declines observed during droughts (which can affect feed and water availability) and upsurges during rainy periods.

Dairy Goats
Stall-based dairy goat farming is a rapidly growing activity in the subcatchment, in part because it requires limited land, capital investment and labor and offers a secure source of income and nutrition for small landholders [5]. Goats are also well adapted to the climate challenges facing farmers in the Nyangores subcatchment, including extremely dry conditions, and can graze on fodder from locally adapted species such as *Calliandra calothyrsus* [13]. While the local market for goat milk remains limited, its higher nutritional value (low in fat and rich in fatty acids and calcium) can benefit farming households. Nevertheless, challenges remain, including lack of markets for milk and goats, the need for capital investment to build initial stocks of improved breeds, timely vaccination and disease treatment, and limited extension services, particularly on value chain promotion and marketing [6]. A tailor-made package of interventions that targets these constraints would provide a useful avenue for scaling up these options.

Climate Stressors and Climate Risks LIVESTOCK		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures and increased evaporation **Increased rainfall variability** **Extreme weather events (drought)**	Increased water scarcity	• Rainwater harvesting in local pans
	Increased costs of animal feed	• Introduction of drought-tolerant forage
	Increased incidence of disease outbreaks	• Increased access to extension services and microfinance
	Increased difficulty of maintaining healthy animals in sanitary conditions	• Construction of more robust sheds and manure storage areas

HUMAN HEALTH

Poverty and poor health are inexorably linked in the subcatchment. Food insecurity, a function of climate-induced crop loss/failure, can leave poor households malnourished, further increasing their vulnerability to illness. The percentage of underweight and stunted children under the age of five in Bomet and Narok counties in 2012, for example, was significant: 12 percent and 35.5 percent, respectively, in Bomet and 11.6 percent and 32.9 percent in Narok. Per capita spending on health financing by county in both counties is at least 50 percent less than the national average (KSh 700 per person compared to the national average of KSh 1,500 per person). A warmer climate is expected to increase malaria and other vector-borne diseases. While many regions of sub-Saharan Africa have grown accustomed to the threat posed by malaria, this mountainous area of Kenya was once thought to be immune to the mosquito-borne disease. Therefore, residents here have little resistance, making outbreaks deadlier than those that occur in areas where the disease is endemic.

Warming temperatures will increase evaporation from water points, furthering the risk of waterborne illnesses through reduced water quality [14] Flooding, particularly because of more intense single rainfall events, can increase drinking water contamination, thereby increasing the risk of waterborne illnesses such as cholera and diarrheal disease. In March 2015, for example, a cholera outbreak in Bomet town killed two people and forced all the city's hotels to close. Improved sanitation is limited, with 35 percent of residents in Narok county and 24 percent in Bomet relying on improved sanitation.

Climate Stressors and Climate Risks HUMAN HEALTH		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures	Increased food insecurity and malnutrition	• Livelihood diversification
	Increased risk of vector- and waterborne diseases, including malaria and cholera	• Implementation of malaria profile of interventions, including the distribution of bed nets
Increased heavy rainfall	Flooding, leading to "pooling" and stagnant water, in turn increasing the risk of waterborne illnesses and contamination of water sources	• Protection/rehabilitation of springs; water boiling and filtering

WATER RESOURCES

The rains and Mau Forest complex are a source of water for the subcatchment. Nevertheless, over 70 percent of the area's residents obtain their water unsafely from ponds, lakes, streams and rivers, as well as unprotected springs and wells. Improved water sources include protected springs, boreholes and rainwater harvesting. These sources are susceptible to encroachment and pollution via land use activities, especially when faced with a more variable climate. In towns, piped water is more readily available: 20 percent of residents in Narok county and 24 percent in Bomet use improved water sources. According to the WRUA, of the 498 springs in the catchment, approximately one-half of these need rehabilitation, as increasingly variable rainfall and unsustainable land use practices such as eucalyptus planting for wood fuel sales reduce or eliminate flows during the critical dry periods. Of these, only 22 have been rehabilitated. As temperatures rise, evaporation rates will clearly increase from existing water points, reducing water quality.

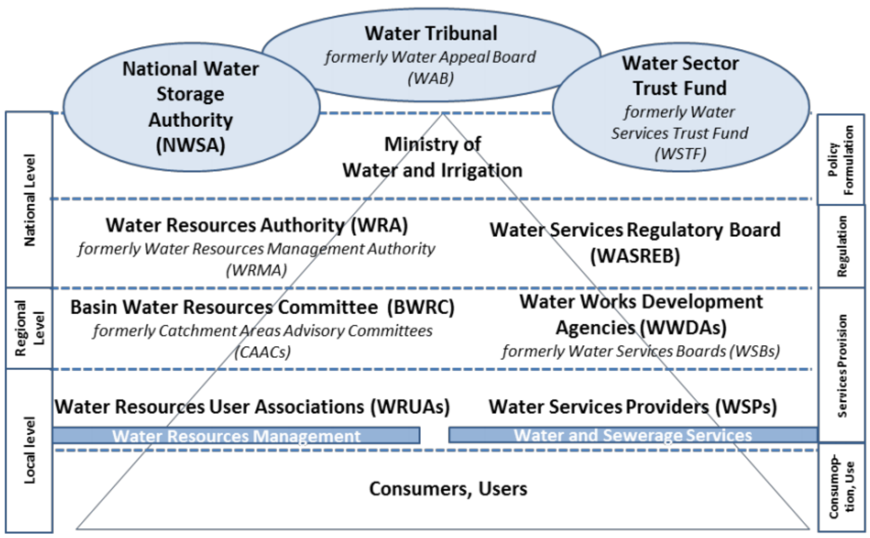
Climate Stressors and Climate Risks WATER RESOURCES		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures **Increased evaporation** **Increased heavy rainfall**	Reduced flows	• Replacement of existing water-loving eucalyptus trees with water-saving species
	Increased sedimentation	• Planting of cover crops along springs to ensure water flows and reduce sediment loads and erosion
	Damage to infrastructure	• Clear drainage networks to guarantee debris flows.
	Reduced flows during critical dry periods	• Protection/rehabilitation of springs; water boiling and filtering

INSTITUTIONAL STRUCTURE FOR WATER MANAGEMENT

NATIONAL FRAMEWORK

Kenya's 2010 Constitution acknowledges access to clean and safe water as a basic human right and assigns responsibility for water and sanitation supply to its newly devolved political governance system of the 47 counties, with budgetary support and oversight roles assigned to the national government. A subsequent 2014 Water Bill identified water management institutions, each with specific roles and responsibilities (see figure below). The country's 2016 Water Act further aligns the process of devolution to the water sector specifically, while also prioritizing domestic uses over irrigation and other uses.

Redefined Roles and Responsibilities under Kenya's 2014 Water Bill



Source: World Bank

WATER RESOURCE MANAGEMENT IN THE NYANGORES SUBCATCHMENT

The Nyangores WRUA was formally established in 2012 but has been in operation as a Community Based Organization since 2008. Membership is estimated at 800, with both active (farmers, industries) and silent (abstractors not formally engaged in the WRUA) members.

The WRUA published its first SCMP in June 2011. This is in line with the legal requirements as stipulated in the Constitution of the Republic of Kenya (2011), the Water Bill (2014), the Water Act (2016) and other related acts. It embraces participatory, evidence-based approaches to the management of water resources that reinforce WRUA stakeholders' ownership of the activities. The SCMP outlines key risks to the subcatchment, including those related to deforestation, lack of enforcement of legal requirements, water scarcity, illegal water abstraction, water use conflicts, lack of rainwater harvesting awareness, and unsustainable quarrying and sand harvesting. The plan promotes the sustainable use of water resources by funding and designing the rehabilitation of critical springs (of the approximately 500 springs in the subcatchment, approximately 50 percent are considered degraded); and focuses on promotion of soil and water conservation measures to support water security. In line with the Bomet county government priorities, the related action plan promotes the replacement of current eucalyptus plantations with water-friendly species such as bamboo.

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ANNEX 2: CASE STUDY – MARA WETLANDS

SUBCATCHMENT OVERVIEW

Located at the lower end of the Mara River in Tanzania, adjacent to Lake Victoria, the Mara Wetlands are riverine swampland dominated by papyrus, with a total area ranging from 390 km^2 to more than 500 km^2, depending on seasonal flooding. Home to a wide array of birds, terrestrial and semi-aquatic mammals, and fish, the wetlands are an important source of habitat for wildlife as well as natural resources for local communities [27].

The wetlands cover four districts of the Mara region – Butiama, Rorya, Tarime and a small portion of Serengeti – which are largely rural (90 percent) and experienced an average population increase of 28 percent between the 2002 and 2012 censuses. Twenty villages surround the wetlands, with a 2012 census population of almost 56,000. Approximately 83 percent of households engage in agriculture as their primary occupation and 98 percent of crops are rainfed [11]. As of 2012, 26.2 percent of the population was below the country's poverty line [12].

Projected increases in temperature, variability in rainfall, frequency and intensity of heavy rainfall events, and intensity and duration of heat waves and drought events, coupled with high levels of poverty and a reliance on rainfed agriculture, make the communities around the wetlands particularly vulnerable to climate change.

CLIMATE PROJECTIONS

- 1.77°C increase in temperatures by 2050
- 10.7–12.5% increase in precipitation by 2050
- Increase in heavy rain events
- Increase in duration of heat waves and dry spells

KEY SECTORS AND VULNERABILITIES

Subsistence crops
Reduced yields and quality
Crop loss from extreme events
Food insecurity

Cash crops
Reduced yield and quality
Crop loss from extreme events
Income losses

Livestock
Increased morbidity and mortality
Reduced productivity
Reduced water and pasture availability

Human health
Undernutrition
Increased risk of malaria
Increased risk of waterborne disease

Water resources
Reduced access to safe drinking water
Damage to water infrastructure

CONTEXT

The case study is aimed at organizations — including the Sustainable Water Partnership, as well as national and local governments, international donors, NGOs and community organizations — developing water use plans, policies and interventions in the case study geography, or within the broader Mara basin. The case study was designed to provide a highly localized vulnerability profile and recommendations for interventions, as well as provide local context for the vulnerability assessment of the Mara River Basin.

The information presented in this case study is based on a review of the plans, assessments and data listed in key resources, and is informed by consultations with 28 community members representing the North Mara Water Users Association (WUA), held in Kwibuse, Tanzania on September 27, 2018. The participatory consultations included a series of exercises designed to understand local vulnerabilities to climate risks and identify the community's adaptive capacity to address these risks. The case study was designed to provide a highly localized vulnerability profile as well as provide local context for the vulnerability assessment of the Mara River Basin. Descriptions of the consultation exercises, along with community responses, are summarized in the case study but are also available in detail in Annex 4 of the USAID ATLAS project's assessment: *Vulnerability and Adaptation in the Mara River Basin*.

PRIORITY VULNERABILITIES AND KEY ACTIONS

WHAT MAKES THE COMMUNITIES OF THE MARA WETLANDS VULNERABLE?

High sustained population growth leading to land conversion. The four districts that surround the wetlands experienced rapid population growth over the past 15 years, averaging an annual growth rate of 2.5 percent, which translates to an increase of almost 28 percent between the 2002 and 2012 censuses [14]. The Mara region as a whole more than doubled in population over the past 30 years, to an estimated current population of over 2 million [12]. This growth in population taxes already scarce resources, which when coupled with a further push toward villagization, has led to the conversion of forest and wetlands to crop and pasture lands. Current estimates suggest that more than 100 km^2 of wetlands have been converted to agriculture [9].

High levels of poverty and food insecurity. The most recent 2011/2012 Household Budget Survey estimated the poverty rate (poverty head count, below the basic needs poverty line) in the region at 26.2 percent, which is just below the national average of 27.5 percent. However, this does mark a decline in the poverty rate from 50 percent in 2000-2001. Food insecurity is particularly pronounced between January and April, when harvested stocks are generally depleted.

Dependence on surface water and other unimproved sources for drinking water. Ninety percent of the population of the wetland's districts is considered rural; as a result, only 25 percent of the population has access to improved drinking water sources, and less than 10 percent to piped drinking water. Instead, the primary sources of drinking water are those that are susceptible to drought and contamination: 23 percent rely on unprotected springs as a primary source of drinking water, 21 percent rely on surface water from rivers and lakes, and 28 percent rely on unprotected wells [12].

Dependence on rainfall for agriculture. Agriculture is the dominant economic activity – almost 83 percent of the working-age population engages in agriculture as a primary occupation. The farms in the area are almost exclusively smallholder, are rainfed and grow a mix of subsistence and cash crops, making them highly vulnerable to the negative impacts of climate variability and change. Less than 2 percent of the planted area is under irrigation, and the water used for irrigation is drawn using hand buckets or is gravity fed from either the Mara River or Lake Victoria [11].

Deforestation and overgrazing. In addition to land conversion driven by a rapidly growing population, cooking fuel sources and livestock production methods contribute to degraded forests and grasslands. Almost 98 percent of the population uses firewood or charcoal as a primary fuel source for cooking, and many often turn to illegal logging and charcoal making during periods of crop loss [12]. During the 2017 drought that caused widespread crop failures, the North Mara WUA estimated that 70 percent of the community turned to illegal forest harvesting. Approximately 95 percent of ruminant livestock in the region are kept under traditional production systems, which depend on grazing and crop residues as the main feed source [15]. Overgrazing and clearing forested land for pasture increase soil erosion, particularly in areas with steep slopes such as those found in Tarime district. This clearing makes the area more susceptible to landslides, flooding, river siltation and soil nutrient loss, all of which will be exacerbated by climate variability and change.

No voice in or control over critical upstream activities. As a transboundary resource, the community and country have limited influence over the upstream portions of the Mara River in Kenya, where agricultural runoff, industry and increased forest clearing have increased siltation and pollution. Major potential dam projects in Kenya — including the 10-meter Norera dam on the Mara River (for irrigation), the 65-meter Amala High dam on the Amala River (for hydropower), and the 30- and 70-meter Nyangores River dams (for irrigation) — could further exacerbate the situation. As it stands, sediment deposition at the river's edge due to upstream activities has increased the wetland's area by pushing backflow toward the wetlands over the last 30 years. The image below shows the extent of the increase in the wetland's area between 1984 and 2016, during a period that typically does not experience flooding (January).

Change in area of the Mara Wetlands from January 1984 (left) to January 2016 (right)

Source: Google Earth

Note: Width of each map image is 64km. The maps show the change in the extent of the Mara wetlands, with the map on the right from 2016 showing a wetland area that has almost doubled in size compared to 1984.

COMMUNITY-IDENTIFIED VULNERABILITIES

Drought and disease (both human and animal) were priority risks identified during the consultations, seen as having significant impacts on crops, livestock, fisheries, and human health. Livestock was seen as the resource most at risk from climate change, ranked highly vulnerable to drought and disease, and moderately vulnerable to flooding and land use change.

CRITICAL ACTIONS

The two wetland WUAs (North Mara and South Mara) have yet to develop their subcatchment management plans (SCMPs) or WUA plans. The only two Mara River subcatchments in Tanzania that do have plans are Somoche and Tabora, both located in Serengeti district. Nevertheless, the *Mara Wetlands Integrated Management Plan 2018–2022* and the *Conservation Investment Plan for Mara Wetlands* form the guiding documents for the wetlands. Both plans are harmonized with the overall goals of the Lake Victoria Basin Commission's *Mara River Basin Transboundary Integrated Natural Resources Management Plan (2016–26).*
To address issues directly related to the impacts of climate variability and climate change as well as community identified vulnerabilities, the following management actions from the *Mara Wetlands Integrated Management Plan 2018–2022* are critical [10]:

- Promoting agroforestry to address soil erosion and land degradation, including providing key inputs, materials, training, and extension to enable on-farm agroforestry.
- Promoting sustainable production and management of livestock, including formulation and enforcement of by-laws regulating entry of cattle into ecologically sensitive areas, as well as support to farmers to access improved livestock breeds, employ reduced-impact feeding techniques, and benefit from new market opportunities.
- Establishing domestic water supply schemes, including formulating plans for enhancement of water supply and storage facilities at village and household levels, implementing water supply and storage upgrades, and establishing maintenance arrangements with local WUAs.
- Controlling soil erosion, including rehabilitating soils, implementing terracing along catchment slopes, and training extension workers on soil management technologies and techniques.

Additionally, other management actions from the management plan should be supported to increase the community's climate resilience, including:

- Enhancing communication and capacity among Mara River Basin stakeholders to support proper conservation and management of the wetland as a transboundary resource.
- Promoting the best climate change adaptation technologies in the Mara Wetlands, including climate-smart agriculture and improved cookstoves.
- Promoting ecosystem restoration and sustainable land management through tree-based business measures such as on-farm tree planting, community and institutional woodlots, and development of associated income-generating and value-adding opportunities (e.g., nurseries and seedling production, small-scale wood processing, and fruit and fodder production)
- Regulating water abstraction, including conducting an environmental flow assessment for the wetlands and using the results to develop abstraction regulations.
- Collating and improving data for the Mara Wetlands and adjacent areas, including regular biodiversity, social and demographic, and water level, quality and quantity surveys, along with repairing existing data stations and restarting regular data collection.

CLIMATE SUMMARY

The Mara River Basin in Tanzania ranges in elevation from almost 1,900 meters in Tarime near the Kenyan border, to 1,100 meters where the Mara River enters Lake Victoria. As a result, rainfall patterns differ throughout the basin. The northern zone covering upper Tarime and the northeastern portion of the Serengeti district has an average rainfall of 1,250 mm to 2,000 mm per year and two rainy seasons that are longer in length than in other portions of the basin: a "long" rainy season (known locally as *masika*) from February to June, and a "short" season (known locally as *vuli*) from September to January. The central zone where the wetlands lie receives annual rainfall of 900 mm to 1,300 mm, and the low-lying areas in southern Serengeti and Butiama districts have an annual rainfall of 500 mm to 800 mm [8]. Rainfall patterns in these two zones are also bimodal, with long rains between March and May and short rains between October and December, and the two seasons are separated by a typically dry season between June and August. Average monthly temperatures range between 13–30°C; the lowest average minimums occur in June and July, and the highest average maximums occur between September and October.

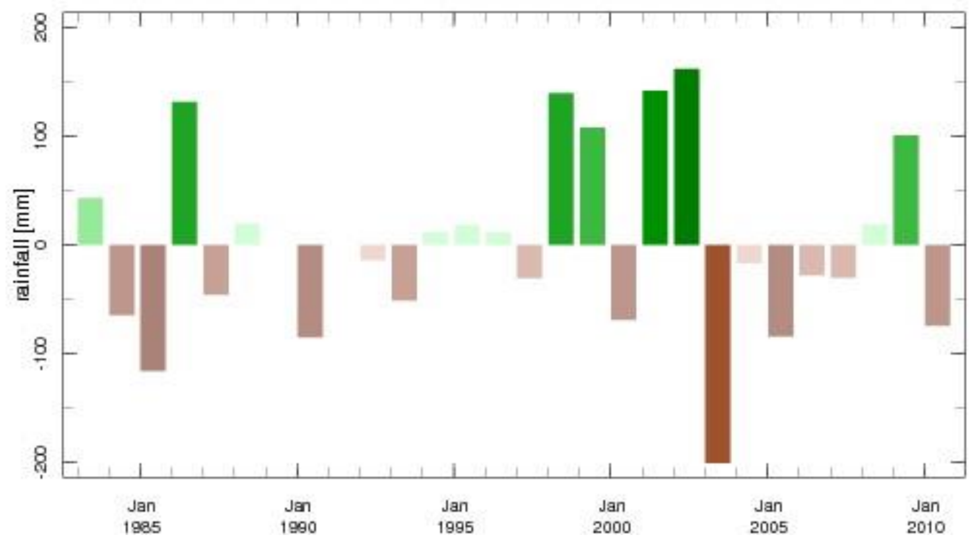
HISTORICAL CLIMATE

Historical climate trends include [20]:

- Increase of 0.9°C in the average maximum temperature at the Musoma station – from 28.0°C in 1961 to 28.9°C in 2014.
- Increase of 1.1°C in the average minimum temperature at the Musoma station – from 17°C in 1961 to just over 18°C in 2014.
- Little change in the trend for average annual precipitation, but rainfall is highly variable from year to year, with flooding events around the 2000s, and droughts in 2003, 2006, 2011 and 2017. The graph below provides a visual representation of the frequency and severity of rainfall variation over the past 30 years.

- Rainfall patterns drive seasonal and interannual water level fluctuations in Lake Victoria; the lake level usually rises from May to July and falls from August to December.
- The wetlands themselves tend to flood annually during the long rains from March to May, and the overall area of the wetlands more than doubled in the past 30 years.

Yearly seasonal rainfall anomalies for Mara Wetlands (1983–2011)



Source: Tanzania Meteorological Agency Map Room [18]

COMMUNITY EXPERIENCE WITH CLIMATE SHOCKS AND CHANGES

In discussions with the community, members of the North Mara WUA described a climate that was highly variable from year to year, with regular drought and flooding events. Two climate events in particular caused larger disruptions: the major flooding during the El Niño event of 1997–1998 and a significant drought in 2017. Two additional non-climate events, which were exacerbated in part by climate variability and change, increased the community's vulnerability: land use changes in the 2010s, and an increase in crop and livestock disease from 2014–2018.

El Niño event (1997–1998). This event caused widespread flooding throughout the East Africa region. The community noted that the event caused major changes in the course of the Mara River in Tanzania, including widening in certain places caused by logs washed down from upstream that blocked the course of the river.

Major drought event (2016–2017). According to FEWS NET, well-below-average September to December *vuli* rains in 2016 resulted in substantial crop loss of more than 50 percent for the season. This was followed by March to May *masika* rains in 2017 that were up to 40 percent below average, resulting in crop production 40 percent below the five-year average and a subsequent spike in food prices. The community dealt with local crop failure and livestock deaths primarily by turning to illegal logging and charcoal making – an estimated 70 percent of the population turned to these sources of income – as well as increasing fishing and small-scale mining operations.

Land use changes (2010–2018). Over the course of the past decade, the community noted that pasture land was either lost – largely due to expansion in wetlands area and in the width of the Mara River – or converted to crop land and human settlements due to a significant increase in population and *ugamaa* (villagization, a move from informal communal land use to formal village-based land use plans).

Increase in crop and livestock disease (2014–2018). In the past five years, the community observed a notable increase in crop diseases (primarily cassava mosaic and maize streak virus) as well as outbreaks of livestock disease during the dry season: Newcastle disease in chickens, foot-and-mouth disease in cloven-hoofed ruminants and *degedege* (convulsions) in sheep and goats.

FUTURE CLIMATE

Projected changes include [20]:

- Increase in average temperatures of 1.77°C across the Lake Victoria Basin zone by 2050, and an increase of 3.3–3.4°C by 2100. The largest increases are expected during the June–August dry season.
- Increase in average rainfall of 10.7–12.5 percent across the Lake Victoria Basin zone by 2050, and an increase of 18.2–23.3 percent by 2100. The two rainy seasons follow the same range of increase, but the June–August dry season is considerably more variable, with projected average rainfall by 2100 to be anywhere between -40.8 percent and +44.6 percent.
- Increased frequency and intensity of heavy rainfall events.
- Increased intensity and duration of heat waves and drought events.

SECTOR IMPACTS AND VULNERABILITIES

AGRICULTURE

The agriculture sector contributes approximately 29 percent to Tanzania's gross domestic product (GDP) and employs 75–80 percent of the working-age population [26]. Eighty percent of agricultural production is rainfed, characterized as low-input smallholder farms highly vulnerable to weather variability. Around the wetlands these figures are even higher: 83 percent of households engage in agriculture as their primary occupation, and less than 2 percent of the planted area is under irrigation. This reliance on rainfall, coupled with low technology, low-input farming techniques on small plots (generally between 1.0–1.5 hectares), makes the agriculture sector vulnerable to climate variability and reduces its resilience to climate change. Projected temperature rise, longer dry spells, and more frequent and intense rains will further put these communities at risk [22].

While use of irrigation, more advanced implements and use of inputs such as improved seeds, fertilizers, pesticides and herbicides is limited (one or more of these advanced practices or inputs are used on less than 10 percent of the total planted area), farmers do employ a number of coping strategies to reduce their risk, including: crop diversification, mixing crops with varying maturity periods (e.g., maize and beans), mixing in drought-tolerant crops (e.g., cassava and sorghum), crop rotation techniques and use of multiple planting periods [7].

Barriers to community uptake of adaptation actions (including those listed below) include: lack of capital to invest in new techniques and technologies; lack of access to improved inputs; lack of awareness of options and training on new techniques; and a low tolerance for risk. Any successful intervention will need to be designed to take these barriers into account.

Subsistence Crops

Maize is the dominant crop, representing approximately 50 percent of the planted area, followed by cassava (32 percent of the planted area), sorghum, beans, sweet potatoes, millet and rice. At the household level maize, cassava and sorghum are the three most important crops, with 0.6 hectares on average devoted to each household plot [11,12]. These districtwide statistics match with community perception; North Mara WUA members ranked the following in order as the most important subsistence crops: maize, cassava, kidney beans and sorghum.

Land preparation in the districts around the wetlands takes place from December through February. Crops are typically planted in the period between January and March or between September and November to coincide with the two annual rainy seasons. The primary harvest period is between June and August after the *masika* rains, with a secondary harvest between December and March after the *vuli* rains, although some household-level crops (e.g., cassava and potato) are harvested throughout the year.

Maize production under a changing climate is expected to decline countrywide in Tanzania, with an average predicted decline of 17 percent in the Lake Victoria Basin region (2,7,16,17,23). Maize is susceptible to both higher temperatures and drought, and does particularly poorly under a hot and dry scenario, with production decreases in the region projected at 10–37 percent [1]. The reliance of wetland communities on maize as both a food source and a source of income, coupled with projected higher temperatures, increased variability in rainfall and greater likelihood of longer, more intense droughts, puts these communities at significant risk in the future. Decline in yields is likely to have the most impact in Tarime district, which has almost double the planted area of maize as the next closest district.

The second most important subsistence crop around the wetlands, cassava, is considerably more drought-tolerant, and serves as a failsafe in the event of maize crop failure. However, cassava is susceptible to prolonged periods of drought, and yields are not likely to keep up with the increased population needs. In the districts around the wetlands, Butiama has the largest area planted with cassava.

Climate Stressors and Climate Risks AGRICULTURE – Subsistence Crops		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures and evaporation rates	Reduced food yields due to heat stress	• Use of drought-tolerant or -resistant varieties of maize • Use of early-maturing crop varieties (e.g., maize, sorghum, sweet potato, beans) • Rainwater harvesting or irrigation
Increase in precipitation variability	Cropping pattern uncertainty	• Change in planting patterns, such as altering rotations or using intercropping • Increased use and availability of climate, weather and early warning information (e.g., Tanzania Meteorological Agency's monthly and seasonal outlooks)
	Reduced yields or quality of crops due to water stress	• Rainwater harvesting, irrigation and water storage • Crop diversification (from maize) to include more drought resistant crops (e.g., sorghum, millet, cowpea, pigeon pea)
Increased frequency and intensity of heavy rainfall	Damage to crops and land from heavy rainfall, flooding, erosion and waterlogging	• Improved soil management (limited tilling, composting, mulching, terracing, fertilizer application) • Adopting agroforestry techniques such as border planting, alley cropping or Sloping Agricultural Land Technology
	Increased pest and disease damage	• Use of pesticides, disease- or pest-resistant varieties, crop rotation or companion planting

Cash Crops

Although all cash crops grown represent less than 10 percent of the total planted area around the wetlands, they are an important source of income. These include primarily oilseeds (e.g., groundnut, sunflower, sesame) and cotton. North Mara WUA members ranked the following in order as the most important cash crops: sunflower, cotton, sesame and excess subsistence crops (including groundnut, which is primarily viewed as a subsistence crop).

The two main cash crops (sunflower and cotton) are sold raw and are processed outside of the community. The Tanzanian government is encouraging cultivation of sunflower seeds, and farmers in the area sell directly to a processing facility located in Namanga on the Tanzanian–Kenyan border. In the case of cotton, farmers form a relationship with the local cotton board, wherein the board provides all inputs, and farmers sell raw cotton to the board, less the cost of inputs.

Sunflowers are generally a hardy and fairly drought-resistant crop, but with projected changes in climate, while yields are not expected to decline, neither are they expected to significantly increase. Cotton farming is water-intensive and relies on rainfall. The projection of an overall increase in precipitation in the area would be beneficial for cotton and yields could increase. However, cotton may be more susceptible to pests (such as the cotton bollworm) that thrive in warmer temperatures and wetter conditions, and is highly susceptible to droughts, which are likely to increase in intensity and duration.

Climate Stressors and Climate Risks AGRICULTURE – Cash Crops		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures and evaporation rates	Reduced yields due to heat stress	• Use of drought-tolerant or -resistant varieties (e.g., groundnuts) • Use of high-yield crop varieties (e.g., cotton) • Rainwater harvesting or irrigation
Increase in precipitation variability	Reduced cotton yields due to sporadic rain	• Rainwater harvesting, irrigation or water storage • Income diversification (from cash crops) to include tree-based business such as fruit trees, community and institutional woodlots, and seedling production • Increased use and availability of climate, weather and early warning information (e.g., Tanzania Meteorological Agency's monthly and seasonal outlooks)
Increased frequency and intensity of heavy rainfall	Damage to crops and land from heavy rainfall, flooding, erosion and waterlogging	• Improved soil management and fertility techniques (limited tilling, composting, mulching, terracing, fertilizer application) • Adopting agroforestry techniques such as border planting, alley cropping or Sloping Agricultural Land Technology
	Increased pest and disease damage	• Use of pesticides, disease- or pest-resistant varieties, crop rotation or companion planting

LIVESTOCK AND FISHERIES

Livestock fulfill a number of functions for communities around the wetlands, including as a source of income, and for consumption, ceremonies and dowry. Sixty-two percent of households keep livestock; cattle, goats, sheep and chickens are the primary livestock in terms of both percentages of animals kept and the community's ranking of their importance.

Cattle have the most economic and social importance –more than 2 million head of cattle are currently kept in the region. Ownership in the region is split between small-scale producers and large operations: one-third of households in the region have one to five cattle (small-scale producers), but approximately one-half of the cattle in the region are owned by less than 1 percent of households with large herds (200+ cattle). The area around the wetlands is almost exclusively small-scale producers that rely on grazing and crop residues for feed.
Tarime and Rorya districts raise primarily indigenous cattle, and account for less than 30 percent of the cattle in the region [11]. Larger concentrations of cattle, particularly dairy and beef cattle, are found in lower-lying areas south of the wetlands in Butiama and Bunda districts. The cattle population has increased dramatically at around 9 percent per year, up almost 1 million head from the official count of 1.1 million in 2003 [8]. Cattle are susceptible to climate variability, requiring large amounts of water and pasture land, and dairy cows in particular are susceptible to increasing temperatures. The communities around the wetlands cited multiple instances in the past 20 years where flooding or drought led to widespread cattle deaths.

Goat, sheep and chickens provide additional income as well as being food sources. Unlike cattle, all three tend to be kept on farm plots or near households, and are stall raised or allowed to graze locally. Although there are large populations of goats (more than 1 million), sheep (more than 500,000) and chickens (more than 2 million), virtually all are kept by small-scale producers with one to ten animals per household, and are indigenous breeds. All three tend to be more climate-resilient than cattle, in part because of lower input requirements, but also because the animals are better adapted to dry conditions and grazing on local fodder. Fish also provide a source of food and income for the population around the wetlands, and are almost exclusively obtained through small-scale capture fishery. Overfishing, siltation and conversion of wetland habitat have all increased pressure on wild fish stocks [9].

Climate Stressors and Climate Risks LIVESTOCK AND FISHERIES		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures and evaporation rates	Heat stress in livestock, leading to reduced reproduction, growth rates and milk production; higher morbidity and mortality	• Use of improved breeds (such as indigenous breeds that are more resistant to diseases and high-yielding)
	Increase in water temperature for fisheries	• Use of cage culture in natural bodies of water or aquaculture
Increase in precipitation variability	Degraded pasture land	• Use of semi-intensive production (free-range combined with intensive systems) • Improved fodder production and grazing management (establishment, stocking rate, rotational grazing)
	Decreased water availability	• Implementation of small-scale dams and boreholes as alternative water sources
Increased frequency and intensity of heavy rainfall	Increase in vector-borne diseases	• Improved access to extension services • Increased use of dipping and spraying
	Losses from floods	• Increased use and availability of climate, weather and early warning information

HUMAN HEALTH

Nineteen percent of children under age five were classified as underweight in 1991, and that number declined to 12 percent in 2010 [25]. In the most recent Tanzania Demographic and Health Survey and Malaria Indicator Survey (DHS-MIS) from 2016, slightly more than 10 percent of children under age five were classified as malnourished according to weight-for-age in Mara region [21]. That can quickly change however, as seen during the 2016–2017 drought. As a result of only two poor harvests over a period of less than a year the region became classified as “stressed” by FEWS NET [6][6]. Increasing demand driven by population pressure, coupled with increased rainfall variability and projected decreases in maize production, could rapidly undo the progress of the past few decades.

[6] Stressed: “Even with any humanitarian assistance at least one in five households in the area have the following or worse: Minimally adequate food consumption but are unable to afford some essential nonfood expenditures without engaging in irreversible coping strategies.” (Integrated Phase Classification v2.0)

The wetlands' climate is categorized as highly suitable for malaria transmission six to seven months out of the year [4]. In the 2016 DHS-MIS, 19 percent of children under age five tested positive for malaria in the region. Tarime in particular has a very high rate of endemicity, with a population-weighted mean prevalence four to seven times higher than neighboring Serengeti or Musoma districts. Based on the projected temperature and precipitation increases, it is thought that most of the region (excluding eastern Serengeti) could become suitable for malaria year-round by 2050 [25].

Waterborne illnesses are also prevalent, and the percentage of children under age five reporting diarrhea in the past year increased from 11 percent of total population in 1991 to almost 18 percent of total population in 2010 [21]. With a large percentage of the population dependent on unimproved drinking water sources, and with an average of 82 percent of the households around the wetlands using non-improved toilet facilities, that trend is likely to increase with warmer temperatures and increased risk of flooding. Cholera in particular is a concern as its prevalence is increased by warming temperatures and is spread by high rainfall events. In 2015 Tanzania experienced a cholera outbreak, and the Mara region was one of the four worst affected regions.

<table>
<tr><th colspan="3">Climate Stressors and Climate Risks
HUMAN HEALTH</th></tr>
<tr><th>Stressors</th><th>Risks</th><th>Illustrative Adaptation strategies</th></tr>
<tr><td rowspan="5">Rising temperatures and evaporation rates

Increase in precipitation variability

Increased frequency and intensity of heavy rainfall</td><td>Increased mortality and morbidity related to heat stress</td><td>• Development of heat warning system
• Improvements to design and ventilation of housing</td></tr>
<tr><td>Increased risk of vector- and waterborne diseases, including malaria and cholera</td><td>• Use of prevention measures such as treated mosquito nets, ventilation, spraying and access to improved drinking water sources
• Implementation of surveillance and predication programs to identify and respond to outbreaks (or potential outbreaks) of malaria and other infectious diseases</td></tr>
<tr><td>Increased food insecurity and malnutrition from decreased agricultural productivity</td><td>• Promotion of diversified cropping systems and mixed agriculture
• Projects on water harvesting and irrigation to enhance water access and availability</td></tr>
<tr><td>Loss of life or displacement due to flooding or landslides</td><td>• Use of erosion control measures
• Increased use and availability of climate, weather and early warning information</td></tr>
<tr><td>Increased risk of vector- and waterborne diseases, including malaria and cholera</td><td>• Use of prevention measures such as treated mosquito nets, ventilation, spraying and access to improved drinking water sources
• Implementation of surveillance and predication programs to identify and respond to outbreaks (or potential outbreaks) of malaria and other infectious diseases</td></tr>
</table>

WATER RESOURES

As mentioned in previous sections, despite proximity to the Mara River, Lake Victoria and even the wetlands themselves, communities around the wetlands underutilize water resources. Additionally, very few households around the wetlands have access to improved drinking water: access ranges from a low of 10 percent in Rorya to 41 percent in Serengeti. Most of those with access to improved drinking water draw it from a public tap or protected well or spring, and less than 10 percent of those with access to improved drinking receive it from water piped to their home or plot [5]. That leaves the majority of the population drawing their water from unimproved sources such as unprotected springs (Tarime), surface water from rivers and lakes (Rorya) or unprotected wells (Butiama).

In the four districts that border the wetlands, anywhere from 30–65 percent of the population relies on unprotected surface water from streams, rivers or the lake as a primary drinking water source, which greatly increases vulnerability to climate variability and change. Members of the North Mara WUA noted that a number of small local streams dried up in the past decade, and more extensive observations around the region noted a signification reduction in the past 10 years, with some local streams drying up completely and some becoming more seasonal. At the other end of the spectrum, an increase in the number of high rainfall events increases the likelihood of those water sources becoming contaminated by upstream mining (e.g., Mara North Gold Mine), agricultural farms and sewerage systems [24].

Climate Stressors and Climate Risks WATER RESOURCES		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures and evaporation rates	Decreased soil moisture and infiltration rates	• Improved soil management techniques (composting, mulching, terracing) and water infiltration designs
Increase in precipitation variability	Reduced access to drinking water due to drying up of small streams and seasonal water decreases	• Projects to enhance access to water, including rainwater harvesting, new boreholes and rehabilitation of local streams
Increased frequency and intensity of heavy rainfall	Increased flooding from heavy rainfall events, threatening water infrastructure and quality	• Climate-proofed design and construction of water sources, such as wells, boreholes, reservoirs and water supply infrastructure
	Increase in pollution from farms and sewerage systems	• Climate-proofed design and construction of farms and sewerage systems to include buffer strips and maintenance of wetlands

INSTITUTIONAL STRUCTURE FOR WATER MANAGEMENT

NATIONAL FRAMEWORK

The Water Resources Management Act (WRMA) No. 11 of 2009 is the primary guiding document for water management in Tanzania, and is overseen by the Ministry of Water. Per the WRMA, water resources in Tanzania are managed at five levels, from national to local: (1) the National Water Board; (2) the nine Basin Water Boards (BWBs); (3) Catchment Water Committees; (4) district councils; and (5) WUAs. In practice, technical and economic powers in the water sector are delegated from the Ministry of Water to the nine BWBs, and rural water supply regulation is delegated to the 185 district councils. The actual provision of water and sanitation services in rural areas is then managed by Community-Owned Water Supply Organizations (COWSOs). Below is a summary table of roles and responsibilities at each level, extracted from the WRMA.

Structure and responsibilities of water management institutions in Tanzania

INSTITUTION	ROLES AND RESPONSBILITIES
Ministry of Water	• Formulating national policy and strategy • Regulating, coordinating, supervising, monitoring and evaluating the execution of the functions
National Water Board (NWB)	• Multisectoral coordination in integrated water resources planning and management • Resolving national and international water conflicts
Basin Water Board (BWB)	• Preparing basin water resources management plans • Developing guidelines and standards for water source structures • Monitoring, evaluating and approving construction and maintenance of water source structures • Approving, issuing, managing and revoking water use and discharge permits • Assessing and managing water resources data • Resolving intrabasin conflicts • Coordinating intersectoral water resources management at the basin level • Constituting WUAs
Catchment and Subcatchment Water Committees	• Coordinating and harmonizing catchment or subcatchment integrated water resources management plans • Resolving water resources conflicts in the catchment or subcatchment
Water Users Association (WUA)	• Managing, distributing and conserving water from a source used jointly by members of the association • Acquiring and operating any permits • Resolving conflicts between members of the association related to the joint use of water or a water resource • Collecting water user fees on behalf of the Basin Water Board • Representing the special interests and values arising from water used for public purposes, such as in an environmental or conservation area, or for purposes of managing groundwater control areas

WATER RESOURCE MANAGEMENT IN THE MARA WETLANDS

The Lake Victoria Basin Water Board (LVBWB) oversees water management in the region, including the Mara River and Wetlands. Under the LVBWB is a catchment committee (equivalent to the WRUA board in Kenya) for the wider Mara River Basin, which consists of 14 WUAs. Around the wetlands themselves two WUAs are responsible for water management: North Mara WUA and South Mara WUA. The North Mara WUA consists of eight villages in Tarime and Rorya districts, representing approximately 31,000 residents from the villages of Kembwi, Bisarwi, Surubu, Nyamerambaro, Nkerege, Marasibora, Kwibuse and Nyanchabakenye. The South Mara WUA consists of eight villages in Butiama district, representing approximately 29,000 residents from the villages of Kitasakwa, Ryamisanga, Buswahili, Kongoto, Wegero, Kwisaro, Kirumi and Bukabwa.

The World Wide Fund for Nature (WWF) has played a large role in the basin over the past 15 years, and both WUAs were formed in 2013 with its assistance. Each association has a constitution and four primary officers – Chairperson, Vice-chairperson, Secretary and Treasurer – who are each responsible for some aspect of planning and financial management.

Discussions with the North Mara WUA identified the following roles and responsibilities of its WUA:

- *Managing sources of water and conserving the environment*. The WUA manages water sources by establishing laws and has the power to fine offenders. The water sources under the North Mara WUA's purview are:
    - Mara River (portion of the river in Tarime and Rorya districts)
    - Springs
    - Dams
    - Natural and manmade wells
- *Solving conflicts over water use*. Village committees and village offices resolve conflicts, with more complicated or intractable conflicts referred to the courts. Common sources of conflict are:
    - Lack of awareness of environmental conservation measures
    - Lack of awareness of the existence of laws that govern the use of water sources
    - Illegal logging for domestic and business purposes along water sources
    - Drowning of cattle in water sources used for domestic purposes
- *Collecting fees.* The WUA collects fees from the eight villages on behalf of the LVBWB. Every water user contributes Tsh 2,000 (less than $1) per year and these fees are used to renovate water infrastructure.
- *Educating the community.* The WUA delivers educational messages to its members on topics such as the benefits of and methods for conserving water sources (e.g., planting trees) and proper livestock grazing.
- *Designing and implementing projects.* The WUA has worked with a number of international nongovernmental organizations (NGOs) (e.g., WWF, Birdlife International) to design and implement projects that improve water sources, such as a beekeeping project sponsored by WWF and community tree-planting events.

RELEVANT WATER AND NATURAL RESOURCE MANAGEMENT POLICIES AND PLANS

In addition to the WRMA, the following documents govern the management of water and natural resources in Tanzania:

- Water Supply and Sanitation Act No.12 of 2009
- National Water Policy 2002 (NAWAPO)
- National Water Sector Development Strategy (WSDS) 2006–2015
- National Climate Change Strategy (2012)
- National Forestry Policy (1998)
- National Environmental Policy (1997)
- National Environmental Action Plan (2012–2017)
- National Environment Management Act (2004)
- Mara River Basin Transboundary Integrated Natural Resources Plan 2016–2026 (LVBC 2016)
- Mara Wetlands Integrated Management Plan 2018–2022
- Conservation Investment Plan for Mara Wetlands

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26. USAID. 2018. Climate Risk Profile – Tanzania
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ANNEX 3: DATA LIST OF SPATIAL INFORMATION COMPILED AND UTILIZED FOR THIS ASSESEMENT

Category	Layer Name	Geographic Extent	Source
Baseline	Mara basin boundary 1k	MRB	http://maps.mamase.org/
	Populated places	World	worldpop
	Mara WRUAs	Kenya	http://maps.mamase.org/
	Mara river network	MRB	http://maps.mamase.org/
	WRUAs	Kenya	http://maps.mamase.org/
	Towns	Kenya	http://maps.mamase.org/
	Roads	World	http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1
	Springs of Nyangores	Kenya	http://maps.mamase.org/
	Counties	MRB	http://maps.mamase.org/
Vulnerability	Mara basin land use classification	MRB	http://maps.mamase.org/
	MRB land cover 1995 and 2015	MRB	African Bioservices Project
	Elevation (30m)	STRM	RCMRD
	Population density by hydrological unit	MRB	Author's calculations from census data
	Population totals by hydrological unit	MRB	Author's calculations from census data
	Population projections by hydrological unit	MRB	Author's calculations from census data
Climate projections	50km resolution tmin, tmax, taverage projections- rcps 2.6, 4.5, 6 and 8.5 multimodel averages	LBV	CMIP5/PREPARED

ANNEX 4: FIELD DATA COLLECTION

NYANGORES WRUA COMMUNITY MEETING – ACTIVITY OUTPUT

Upper Nyangores livelihoods

LIVELIHOODS	TYPE	MEN	WOMEN	BOTH	IMPT
Agriculture	Tea			x	3
	Maize			x	3
	Potatoes			x	3
	Beans			x	3
	Avocado			x	2
	Passion fruit			x	2
	Tree tomatoes			x	1
	Cabbage			x	2
	Kale			x	2
	Tomatoes			x	2
	Millet		x		1
	Sorghum		x		1
	Banana		x		3
Livestock	Dairy cows	x			3
	Dairy goats		x		2
	Poultry		x		3
	Rabbits	x			1
Business	Agroforestry	x			3
	Bee keeping	x			1

Note: 3 is highest importance, 1 is lowest

Lower Nyangores livelihoods

LIVELIHOODS	TYPE	MEN	WOMEN	BOTH	IMPT
Agriculture	Sweet potatoes		x		3
	Maize			x	3
	Onions		(small scale)	(large scale)	2
	Beans			x	3
	Peas			x	1
	Watermelon			x	1
	Tomatoes			x	2
	Pumpkins		x		2
	Butternut squash		x		1
	Carrots		x		1
	Tobacco	x			1
	French beans	x			1
	Sugar cane	(large scale)	(small scale)		2
	Banana			x	3

LIVELIHOODS	TYPE	MEN	WOMEN	BOTH	IMPT
	Sorghum		x		3
	Millet		x		3
	Boma Rhodes	x			3
Livestock	Dairy cows	x			3
	Beef cattle	x			3
	Dairy goats		x		3
	Poultry		x		2
Fishing	Generic fish	x			1

Note: 3 is highest importance, 1 is lowest

Upper Nyangores vulnerability matrix

	DROUGHT	FLOODS	LAND USE CHANGE	DISEASE (HUMAN AND ANIMAL)	ERRATIC RAINS	*TOTAL*
Tea	2	0	2	1	1	***6***
Maize	3	1	3	3	2	***12***
Potato	3	2	2	3	2	***12***
Beans	3	1	1	2	1	***8***
Dairy cows	3	0	2	2	1	***8***
Poultry	0	0	1	3	1	***5***
Agroforestry	1	0	2	1	0	***4***
Bananas	2	0	1	2	1	***6***
Avocado	2	0	1	1	1	***5***
Total	***19***	***4***	***15***	***18***	***10***	

Note: 3 is high vulnerability, 1 is low

Lower Nyangores vulnerability matrix

	DROUGHT	FLOODS	LAND USE CHANGE	DISEASE (HUMAN AND ANIMAL)	ERRATIC RAINS	*TOTAL*
Sweet potato	1	3	2	1	1	***8***
Maize	3	3	2	3	3	***14***
Beans	3	3	2	2	3	***13***
Bananas	1	0	0	0	0	***1***
Dairy cows	3	2	1	3	2	***11***
Beef	3	2	3	2	2	***12***
Goats	1	2	2	1	1	***7***
Poultry	1	3	1	3	1	***9***
Sorghum	1	1	2	1	1	***6***
Boma rhodes	3	1	1	0	1	***6***
Total	***20***	***20***	***16***	***16***	***15***	

Note: 3 is high vulnerability, 1 is low

Upper Nyangores seasonal calendar

ACTIVITY	SUB-ACTIVTY	J	F	M	A	M	J	J	A	S	O	N	D
Agriculture													
Long rains				X→	X	X	X	X	X				
Dry season		X→	X										
Short rains											X→	X	X
Crop planting													
	Tea				X								
	Maize										X→	X	X
	Potatoes	X	X	X	X	X	X	X	X	X	X	X	X
	Beans				X→	X	X	X	X				
	Bananas	X	X	X	X	X	X	X	X	X	X	X	X
	Sorghum										X→	X	X
	Boma rhodes						X→	X	X				
	Millet										X→	X	X
	Agroforestry				X→	X							
Crop harvesting													
	Tea	X	X			X→	X	X	X	X	X	X	X
	Maize						X→	X	X				
	Potatoes	X	X	X	X	X	X	X	X	X	X	X	X
	Beans								X→	X	X		
	Bananas	X	X	X	X	X	X	X	X	X	X	X	X
	Sorghum						X→	X	X				
	Boma Rhodes (every 3 months)												
	Millet						X→	X	X				
	Agroforestry (when mature)												

Lower Nyangores seasonal calendar

ACTIVITY	SUB-ACTIVTY	J	F	M	A	M	J	J	A	S	O	N	D
Agriculture													
Long rains				X→	X	X	X	X	X				
Dry season		X→	X										
Short rains											X→	X	X
Crop planting													
	Sweet potato		X										
	Maize	X									X→	X	X
	Beans					X→	X						
	Banana	X	X	X	X	X	X	X	X	X	X	X	X
	Sorghum (w/ maize)	X										X→	X
	Millet (w/ maize)	X										X→	X
	Boma rhodes					X→	X						
Crop harvesting													
	Sweet potato						X						
	Maize						X→	X					
	Beans								X→	X			
	Banana	X	X	X	X	X	X	X	X	X	X	X	X

ACTIVITY	SUB-ACTIVTY	J	F	M	A	M	J	J	A	S	O	N	D
	Sorghum (w/ maize)						X→	X					
	Millet (w/ maize)						X→	X					
	Boma Rhodes (every 3 months)												

Nyangores historical timeline

TIME PERIOD	EVENT
1990-1999	
• 1991	Severe drought
• 1994	Drought
• 1995-1997	South African eucalyptus introduced; begins encroaching on river banks
• 1997	El Niño
• 1998-present	Blum gum introduced; invades swamps and increases siltation
1990’s (general)	• Unregulated used of chemicals • Beginning of malaria cases
2000-2009	
• 1999-2000	Severe drought
• 2000	End of fanyu-juu terracing program
• 2004	Severe drought (lower Nyangores)
• 2008	• Deforestation (lower Nyangores) • Cyprus aphids
• 2009-2012	Maize affected by mold
• 2010	Sand quarrying on steep hills leads to collapse
2010-2018	
• 2011	Bee colonies disappearing
• 2014	• White fly outbreak • Frost affects all crops
• 2014-2015	Cholera outbreak
• 2015	Invasive species introduced (yellow plant growing on trees)
• 2016	• Severe drought • Forest fires
• 2017-2018	• Fall army worms affect maize
• 2018	• Nairobi fly • Intensified encroachment • Flooding and landslides (upper Nyangores)

MARA NORTH WRUA COMMUNITY MEETING – ACTIVITY OUTPUT

Mara North community livelihoods

LIVELIHOODS	TYPE	MEN	WOMEN	BOTH
Agriculture	Maize			x
	Sorghum			x
	Millet			x
	Potato		x	
	Cassava			x
	Groundnuts			x
	Cotton			x
	Sesame			x
	Sunflower			x
	Kidney beans			x
Livestock	Cattle	x		
	Pigs	x		
	Goats	x		
	Sheep	x		
	Chickens		x	
	Ducks		x	
	Donkeys	x		
Fishing	Generic river fish	x		
Business	Selling fresh and smoked fish			x
	Cash crops (sunflower, cotton, sesame and excess)			x
	Livestock (auction)	x		
	Retail shops			x
	Restaurants		x	
	Lodging			x
Mining	Gold (private companies)			x
Bodaboda	Motorcycle taxi	x		
Handicrafts	Reed mats and baskets			x

Mara North vulnerability matrix

	DROUGHT	FLOODS	DISEASE (HUMAN AND ANIMAL)	LAND USE CHANGE	CLIMATE INVESTMENTS	TOTAL
Agriculture	3	1	2	1	0	**7**
Livestock	3	2	3	2	0	**10**
Business	1	1	2	0	0	**4**
Fishing	3	0	1	0	2	**6**
Children going to school	2	2	2	0	0	**6**
Impacts on women	3	1	2	1	0	**7**
Mining	2	3	2	0	0	**7**
Impacts on men	2	1	2	1	0	**6**
Handicrafts	1	2	1	0	0	**4**
Total	***20***	***13***	***17***	***5***	***2***	

Note: 3 is high vulnerability, 1 is low

Mara North seasonal calendar

ACTIVITY	SUB-ACTIVTY	J	F	M	A	M	J	J	A	S	O	N	D
Agriculture													
Long wet season (Masika)				X→	X	X							
Short wet season (Vuli)										X→	X	X	X
Land preparation		X	X										X→
Crop planting													
	Sorghum		X→										
	Maize			X→									
	Millet		X→										
	Sunflower			X→									
	Potato			X→	X								
	Cassava	X→	X	X	X	X					X→	X	X
	Cotton	X										X→	X
	Sesame	X→	X										
	Groundnuts												X
	Kidney beans												
Crop harvesting (*Masika*)													
	Sorghum						X→	X	X				
	Maize							X→	X				
	Millet						X→	X					
	Sunflower							X→	X				
	Potato						X→	X	X	X	X	X	X
	Cassava	X→	X	X	X	X	X	X	X	X	X	X	X
	Cotton						X→	X					
	Sesame						X→	X					
	Groundnuts				X→	X							
	Kidney beans					X→	X						
Crop harvesting (*Vuli*)													
	Sorghum	X→	X										
	Maize		X→	X									
Crop disease													
	Maize		X→	X	X	X					X→	X	X
	Cotton	X										X→	X
	Cassava	X→	X	X	X	X	X	X	X	X	X	X	X
	Groundnuts						X	X					
	Potato								X	X			
Livestock		X→	X	X	X	X	X	X	X	X	X	X	X
Fishing		X→	X	X	X	X	X	X	X	X	X	X	X
Business		X→	X	X	X	X	X	X	X	X	X	X	X
Mining		X→	X	X	Heavy	Rains	X	X	X	X	X	X	X
Bodaboda		X→	X	X	X	X	X	X	X	X	X	X	X
Handicrafts		X→	X	X	Heavy	Rains	X	X	X	X	X	X	X
Festivals										X→	X	X	X

Mara North historical timeline

TIME PERIOD	EVENT
1990-1999	
• 1992-1993	Major cholera outbreak
• 1994-1995	Cattle rustling
• 1997	Drought
• 1998	El Nino (high rainfall)
	Major changes in the course of the Mara River
	• Widening in certain places
	• Logs from upstream blocked the course of the river
2000-2009	
	Droughts with moderate rainfall, no major events
2010-2018	
	Droughts with moderate rainfall
	Many springs dried up during this period
	Land use changes
	• Population increase
	• Lost grazing to agriculture and human settlements
	• Ugamaa (villagization) – move from informal communal land use to formal village-based land use plans
	• Loss of grazing land due to expansion of Mara river
	• Introduction of invasive species
• 2014-2018	Increase in cassava disease
	Increase in banana disease
• 2016-2018	Increase in maize disease
• 2017	Major drought event
	• Major increase in food prices
• 2018	High rainfall year
	• Cattle deaths along the banks of the Mara due to overconsumption of water and grass (March-present)
	• Cattle deaths could be due to water contamination from upstream mines
• 2015-2018	Outbreaks of chicken disease starting in July
	Outbreaks of foot and mouth disease during dry season
	Outbreaks of degedege (convulsions) in sheep and goats

Tarime hazard map

VILLAGE	VULNERABILITY
Nkerege	
• Lower (Between Mara river and Myamongo Road)	Crops, livestock
• Upper (Above Myamongo Road)	Crops, livestock, women
Kembwi	
• Lower (Between Mara river and Myamongo Road)	Crops, livestock
• Upper (Above Myamongo Road)	Crops, livestock, women
Bisarwi	
• Lower (Between Mara river and Myamongo Road)	Crops, livestock
• Upper (Above Myamongo Road)	Crops, livestock, women
Surubu	

VILLAGE	VULNERABILITY
• Lower (Between Mara river and Myamongo Road)	Crops, livestock
• Upper (Above Myamongo Road)	Crops, livestock
Nyame Rambare	
• Lower (Between Mara river and Komaswa-Nyamerambara Road)	Livestock, women
• Middle (Between Komaswa-Nyamerambara Road and Myamongo Road)	Crops, livestock, women
• Upper (Above Myamongo Road)	Women

Rorya hazard map

VILLAGE	VULNERABILITY
Mara Sibora	
• Mara adjacent	Crops, student, fisheries
Kwibuse	
• Mara adjacent	Crops, livestock
Nyancha Bakenye	
• Near Mwanza Road	Crops, women

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