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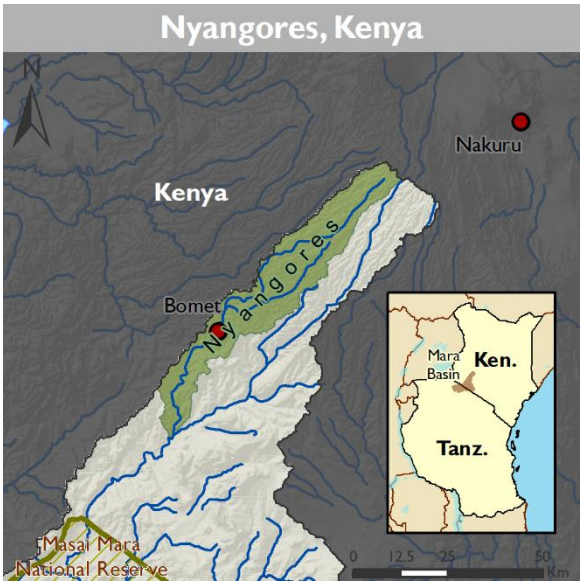
CASE STUDY

VULNERABILITY PROFILE
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

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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.

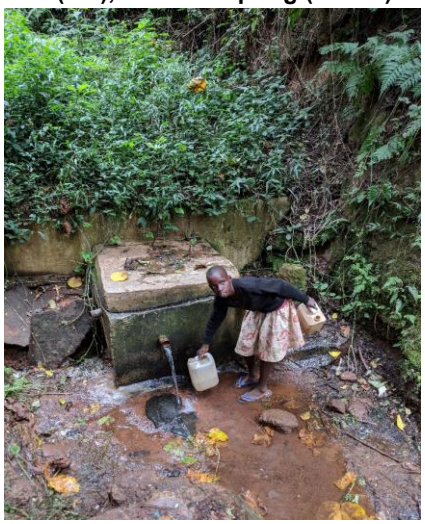
CRITICAL ACTIONS

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, "S*eason-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.

Climate Stressors and Climate Risks AGRICULTURE – Cash Crops		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures **Increased evaporation** **Increased rainfall variability** **Extreme weather events (drought, hail and frost)**	Yield losses	• Mulching, terracing, pruning of tea crops
	Crop failure	• On-farm diversification using viable alternatives such as avocado, banana, passionfruit and tree tomato
	Soil erosion	• Terracing and mulching of tea plantations
	Reduced soil moisture	• Mulching, use of leguminous cover crops

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.

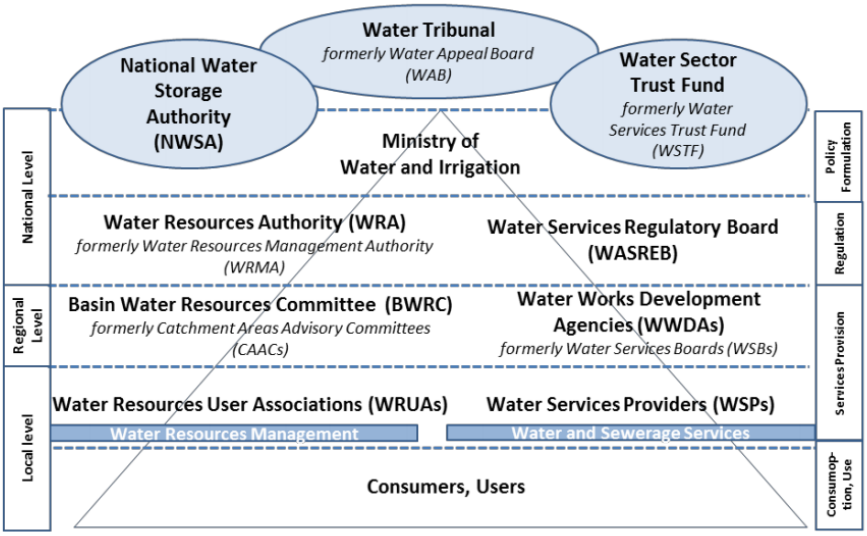
Climate Stressors and Climate Risks WATER RESOURCES		
Stressors	**Risks**	**Illustrative Adaptation strategies**
Rising temperatures	Reduced flows	• Replacement of existing water-loving eucalyptus trees with water-saving species
Increased evaporation	Increased sedimentation	• Planting of cover crops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

KEY RESOURCES

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