Final Report

The role of the riparian zone ecosystem in climate change resilience of communities around Lake Kibare, Kayonza District, Rwanda

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Kigali, 2021

Executive Summary

Riparian zone around streams, rivers and lakes are critical ecosystems in climate adaptation. The vegetation from the riparian zone improves surface and ground water quality, provides food and habitat for animal species, contributes to erosion control and floods. The whole riparian zone at Lake Kibare was used for agriculture and pastoralism until 2018 when REMA made an effort to restore it and ban all activities which were taking place there except conservation. This study aimed to understand how the riparian ecosystem at lake Kibare helps the local community to adapt to climate change. The land use and plant survey were conducted in the riparian zone to understand trees and herbaceous species composition. The literature review was then conducted to know the potential of each tree species to people and how they help local communities to adapt to climate change. Further, the focus group discussion with community members was conducted to get perceptions of local people about the importance of the riparian zone and its role for climate change resilience. Seventeen tree and twelve shrub species distributed in 21 families were recorded in the riparian zone dominated by the Fabaceae family with five species, and the Anacardiaceae with three species. Results from the focus group discussion indicated that the riparian zone protects the lake from flooding and erosion, improves water quality especially when the lake is flooding and provides spawning areas for fishes. They also reported that the riparian zone acts as the buffer zone for wild animals such as *Syncerus caffer* (African buffalo). Monitoring the riparian zone at lake Rwakibare and its services is recommended.

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Chapter 1. Introduction

1.1. Study background

Ecosystems provide services that help people to adapt to climate change by providing food, clean water and by regulating climate and controlling floods, thereby reducing risks associated with climate change (IUCN, 2016). Resilient ecosystems are very important to human well-being and are critical tools supporting communities' efforts to adapt to climate change (Chong, 2014). By definition, resilience is the ability of an ecosystem to absorb disturbances while retaining the same basic structure and ways of functioning as well as the capacity to adapt to stresses and changes (IPCC, 2007). In climate change context, community resilience is the capacity for the community to rebound or recover after a climate change shock (Gunderson, 2010).

Community resilience to climate change is intertwined with ecosystem resilience. Schröter et al., (2005) argue that every environmental problem is a human problem and that the reverse is not necessarily true. For example, changes in the water provision affect humans in many ways, whether direct or indirect through effects on other ecosystem services in the area (Schröter et al., 2005). The role of ecosystems in communities' adaptation to climate change is encapsulated by the concept of 'Ecosystem-based adaptation (EbA).

EbA is defined as deliberate use of biodiversity and ecosystem services as part of an overall adaptation strategy to adverse impacts of climate change (CBD, 2009a). EbA consists of many activities such as catchment management to prevent droughts and floods, rangeland ecosystem management to prevent desertification; and sustainable management of agroforestry and forestry resources to improve food security (Chong, 2014). Further, EbA approach addresses climate based challenges by linking climate change, biodiversity and sustainable resource management to enhance ecosystems which in turn enable society to better mitigate and adapt to climate change (Naumann et al., 2011).

After recognizing that linkage, Rwanda embraced the EbA approach through forests, wetlands and savanna restoration to enhance resilience of people living around these important ecosystems. In wetlands, the focus was about riparian zone restoration and protection. The motivation to focus on riparian zones is because its vegetation improves surface and ground water quality, provides food and habitat for animal species (Hongyong et al., 2016), contributes to erosion control and floods (Laslier et al., 2019), and reduces nutrient to flow into wetlands, rivers and lakes (Stutter et al., 2019).

The existing legal framework in Rwanda also supports the riparian zone protection. For example, the government of Rwanda established the ministerial order N°007/16.01 of 15/07/2010 determining the length of land on shores of lakes and rivers transferred to public property (MoE, 2010). The order specifies that the land within fifty meters (50m) from lakeshore is a public property, and no other activities are allowed to take place there except conservation activities. In this regards**,** the Government of Rwanda through the Rwanda Environment Management Authority (REMA) has declared the riparian zone of Lake Kibare as a conservation area in 2018.

Afterwards, REMA deployed efforts to restore the area by relocating the market outside of the riparian zone. In addition, REMA demarcated the boundaries of the riparian zone and restricted all agricultural activities in the riparian zone. Further, it has planted trees to assist the restoration process. REMA did this under the project entitled "Building resilience of communities living in degraded wetlands, forests and savannas of Rwanda through an ecosystem-based adaptation approach" (REMA, 2019c). However, this project's success and sustainability will largely depends on the community's perception on the riparian zone and its role to enhance climate change resilience.

Understanding community's perception of climate change hazards and how these perceptions affects their willingness to adopt adaptation strategies is very important for developing effective climate change adaptation programs especially in agriculture sector (Li et al., 2017). This is true because adaptation programs often rely on the willing involvement of intended beneficiaries (Patt & Schröter, 2008). Local people's perceptions on climate change are among more important elements influencing adoption of climate change adaptation strategies (Nyanga et al., 2011).

According to the Theory of Planned Behavior (TPB) developed by Ajzen (1985), the most critical determinant of an individual's behavior is his or her intentions to perform the behavior. Behavioral intentions are governed by three main components: attitudes, subjective norms, and perceived behavioral control. Attitudes are our likes and dislikes towards things, people, and objects. People's attitudes about things are developed from their values and beliefs about these things (Jozic, 2019). Subjective norms are based on an individual's perception of whether important people in their life would want them to engage in the behavior, whereas perceived behavioral control reflects the individual's perception that the behavior is either easy or difficult to perform (Fielding et al., 2005). The TPB provides a useful framework for understanding possible factors influencing local people's perceptions of and behavior towards riparian zone management.

This study focuses on the riparian zone of Lake Kibare located in Kayonza District. It explores the role of plant species present in the riparian zone in community's climate change resilience and perceptions of local people to the role of the riparian zone in climate change resilience. This study also examine the current land use and erosion signs in the riparian zone.

1.2. Problem statement

Before 2018, much of the riparian zone of Lake Kibare was severely degraded because of the unsustainable agriculture. Apart from the fact that Lake Kibare is located in the Eastern Province, the driest province in Rwanda, its riparian zone is frequently flooded. Water causing floods in the area is not necessarily coming from the local rain but from the overflow of the Akagera river (REMA, 2019a). Under the project entitled: "Building resilience of communities living in degraded wetlands, forests and savannas of Rwanda through an ecosystem-based adaptation approach" (LDCF II Project), REMA restored the land and banned all other activities, which were taking place in the riparian zone in line with the ministerial order mentioned above.

Before restoration activities begin, REMA explained to local people about the ministerial order protecting the riparian zone and informed them that they should leave that land for conservation. This was communicated through community meetings. However, some people are still resisting to leave the land and they are still cultivating and rearing cattle in the riparian zone illegally. This study determined the proportion of the land used for agriculture and pastoralism, the part which is only for conservation and the part which is covered by papyrus which is native in the area. This research also examined the role of trees and shrubs species present in the riparian zone and assessed the perception of local people on the role of the riparian zone in climate change resilience. This research will guide future restoration activities and the development of education and awareness raising campaigns to local people, based on what they already know.

1.3. Objectives

1.3.1. Main objective

This research seeks to assess the actual and perceived role of the Lake Kibare riparian zone in climate change resilience.

1.3.2. Specific objectives

1.To examine the state of the riparian zone ecosystem (focusing on plant species composition, land use and percentage of eroded soil) in relation to climate change resilience

2.To assess the contribution of the restored riparian zone to the livelihood of local communities

3.To assess perception of local communities about the role of the restored riparian zone in climate change resilience

1.4. Research questions

1. What are plant species present in the riparian zone and how are they contributing in climate change resilience?

2. How has the riparian zone restoration affected community livelihoods?

3. How do local people perceive the riparian zone management in relation to climate change resilience?

Chapter 2. Literature Review

Climate change is a threat to livelihoods in rural communities, affecting mostly agriculture and livestock farming sector (West et al., 2017). Climate change also affect biodiversity, with negative impacts on human well-being (CBD, 2009b). Continued climate change is expected to have adverse and irreversible impacts on ecosystems and their associated services, with significant negative social, cultural, and economic consequences to human. However, Biodiversity can contribute to climate change mitigation and adaptation through its ecosystem services (Gunderson, 2010). By recognizing this, the Convention on Biological Diversity (CBD) introduced the idea of EbA, an approach which uses biodiversity in climate change adaptation for both ecosystems and communities in a cost-effective way (CBD, 2009b).

Maintaining species and genetic diversity prepare ecosystems for whatever environmental changes might happen, and this is fundamental to the concept of ecological resilience (Thompson et al., 2009). Species have two main environmental change adaptation mechanisms. They can migrate to a more favorable environment, or they can change their genetic composition to favor genotypes that are better adapted to the changed environmental conditions (Reusch et al., 2005). Species can also adapt through phenotypic plasticity, if their genotype entails a range of permissible responses that are suitable to the new environmental conditions (Nussey et al., 2005).

On the other side, a community’s climate risks and coping capacities can be assessed by considering both resilience and vulnerability (Bergstrand et al., 2015). People’s vulnerability differs from one household to another depending on many factors (Damas and Israt, 2004). These includes but is not limited to the size of families, amount of income generated per family and heavy reliance on rain-fed subsistence agriculture (Shewmake, 2008). Poor and landless households, children, women and large sized families are also more affected by climatic shocks (Majahodvwa et al., 2013). Other factors determining households’ vulnerability to climate change include low levels of education, gender inequality and lack of access to resources and services (Damas and Israt, 2004). While vulnerability is more about conditions that make communities more susceptible to harm, resilience refers to coping with and recovering from the climate change hazard that has already occurred (Bergstrand et al., 2015).

Plants can contribute to both ecological and communities' resilience. For example, plants can counteract the impacts of drought by increasing water infiltration via root penetration of the soil surface, reducing wind velocity, reducing water loss through shading, enhancing the recycling of water vapor and promoting greater productivity at higher trophic level through the provision of food and habitat (Espeland & Kettenring, 2018). Similarly, plants buffer flood effects largely by increasing infiltration of excess water at a given site (Espeland & Kettenring, 2018). In addition, plants are resilient in the sense that they may recover, after a period, from a catastrophic disturbance to their original state. However, when climate change results in a significant reduction in water availability, plant communities can naturally change species composition to meet the new environmental conditions (Thompson et al., 2009).

The nature of how plants are both influenced by and influence their environment is very important to understanding the extent of and limits to the role of plants in climate resilience (Espeland & Kettenring, 2018). Plants respond differently to climate change stimuli (Gray & Brady, 2016). For this reason, intentional plantings to reduce the environmental impact of drought should focus on planting of drought tolerant plants and afforestation (Chong, 2014).

Most riparian zones are highly modified due to human-induced disturbances (Richardson *et al.*, 2007). In addition, continued human population growth will lead to further degradation (IPCC, 2007). Agricultural intensification, dams, land use change, timber harvesting, fire and the increased spread of invasive species are some anthropogenic threats to riparian zones *(*Poff et al., 2011). Riparian degradation impacts the chemical, biological and physical aspects of water bodies and adjacent upland areas which exacerbate climate change effects (Richardson *et al.*, 2007)

Riparian ecosystems are likely to be particularly vulnerable to climate change impacts because of their relatively high levels of exposure and sensitivity to changes in climatic variables (Capon *et al.*, 2013). Their topographic position exposes them to extreme climatic events, including floods, droughts and intense storms (IPCC, 2007). Fortunately, riparian zones are relatively more resilient to extreme events because many riparian plants are adapted to hydrologic disturbances and tolerate both seasonal and annual variation in environmental conditions (Seavy et al., 2009).

For successful management of riparian zones, conservation of these areas by local communities is needed (Nelle, 2014). When people recognize ecosystem services provided by the riparian zone, they are more likely to implement programs that reinforce riparian zone conservation and effective management (Cossío and McClain, 2017). In contrast, when local land owners don't value riparian zones, education and outreach programs can increase their understanding of why riparian zone conservation is beneficial (Nelle, 2014).

Rwanda is highly vulnerable to climate change risks mostly due its reliance on rain-fed agriculture (REMA, 2011). It ranks 114 out of 181 countries in the Notre Dame-Global Climate Change Adaptation Index (ND-GAIN, 2019). ND-GAIN is an index that shows a country's current vulnerability to climate disruptions and its readiness to leverage private and public sector investment for adaptive actions (Chen et al., 2015).

Rwanda's vulnerability is also exacerbated by its dependence on natural resources (REMA, 2011). Therefore, Rwanda's future socio-economic development is uncertain with its growing population causing further pressure on ecosystems (REMA, 2011). In the context of this research, the term vulnerability is defined as "the degree to which a system is susceptible or unable to cope with adverse effects of climate change" (IPCC, 2007).

Rwanda has experienced a temperature increase of 1.4°C since 1970 (REMA, 2011) and it is facing limited access to water caused by its scarcity, which is becoming a serious problem (Gasirabo et al., 2019). Fortunately, the government of Rwanda developed strategies to adapt to changing climate in the water sector to avoid further vulnerability to water shortages. In the recently submitted Nationally Contribution to UNFCCC, three main strategies are proposed. These are: 1) A national water security through water conservation practices, wetlands restoration, water storage and efficient water use, 2) Water resource models, water quality testing and hydro-related information and 3) Develop and implement a management plan for all level 1 catchments (GoR, 2020).

Rwanda is divided into four main climatic regions: the eastern plains, central plateau, highlands, and regions around Lake Kivu. The eastern plains (Eastern Province) which is the driest among other regions receive an annual rainfall of between 700 mm and 1,100 mm. The mean annual temperature is between 20°C and 22°C (GoR, 2020). The Eastern Province is a flat area (generally no mountains) whose ecosystems are mostly savanna. The altitude in this area is below 1,500 meters (MIDIMAR, 2015). In this province, 51.9% of the total income originates from agriculture (NISR, 2012). According to the same source, other source of income in the Eastern Province are wages (22%), business (9.4%), public transfers (1.5%), and private transfers (6.1%) and rents (9.1%).

A vision for 2050 aims to develop Rwanda with low carbon domestic energy resources and practice (REMA, 2011). Reference to the same source, Rwanda would have the robust local and regional knowledge to help respond and adapt to changes in the climate and the resulting impacts. Toward this end, Rwanda has committed to restore forest landscapes to improve ecosystem quality and resilience, provide new opportunities for rural livelihoods, while securing adequate water and energy supplies, and supporting low carbon economic development (MINIRENA, 2014).

Farmers are important decision makers about land use for effective climate change adaptation (Arbuckle et al., 2013). Their attitudes and perceptions toward the environment is associated with their behavior (Vaske & Donnelly, 1999). Studies on sustainable agriculture adoption have found positive associations between awareness of environmental issues, attitudes toward possible solutions, and willingness to adopt those solutions (Prokopy et al., 2008). Therefore, beliefs about the existence of climate change and potential solutions can predict the adoption of conservation strategies (Arbuckle et al., 2013). This research reports the status of the Lake Kibare riparian zone following EbA interventions through the LDCF II project, how shrubs and trees present enhance climate change resilience and perception of local people on the role the riparian zone in climate resilience.

Chapter 3.Method

3.1.Study area description

This study was conducted in the riparian zone of Lake Kibare located in the Eastern Province, Ndago sector, Rwanda (Figure 1). Lake Kibare has an area of 336 ha and it is a critical source of fishes. Nile Tilapia, African Catfish and *Haplochromis sp* are most dominant in the Lake (REMA, 2019d). In this study, the riparian zone is the area within 50 meters from the lakeshore as determined by the Rwandan Ministerial Order N°007/16.01 of 15/07/2010 determining the length of land on shores of lakes and rivers transferred to public property (GoR, 2010). Villages namely, Kibare, Gafunzo, Kanyinya, Kagese and Kagoma surround the lake. Before, 1997, the whole Ndego sector was part of the Akagera National Park (ANP). The lake is important for local people as a source of water. However, water in this lake is mostly polluted by the Akagera River which flows into the lake from the north (REMA, 2019b). In addition, Kayonza District where Lake Kibare is located is among the drought prone areas in Rwanda (Mudahunga & Ndagijimana, 2018)

Sedimentation and pollution are major problems faced by the Lake Kibare riparian zone. In addition, increase mean temperature and erratic rain fall negatively affect the local community buy decreasing the agricultural productivity, water quality and quantity and fish stock. To alleviate these problems mainly caused by climate change, REMA selected this Lake for EbA interventions through the LDCFII Project. Under this project trees were planted for the riparian zone to restoration.

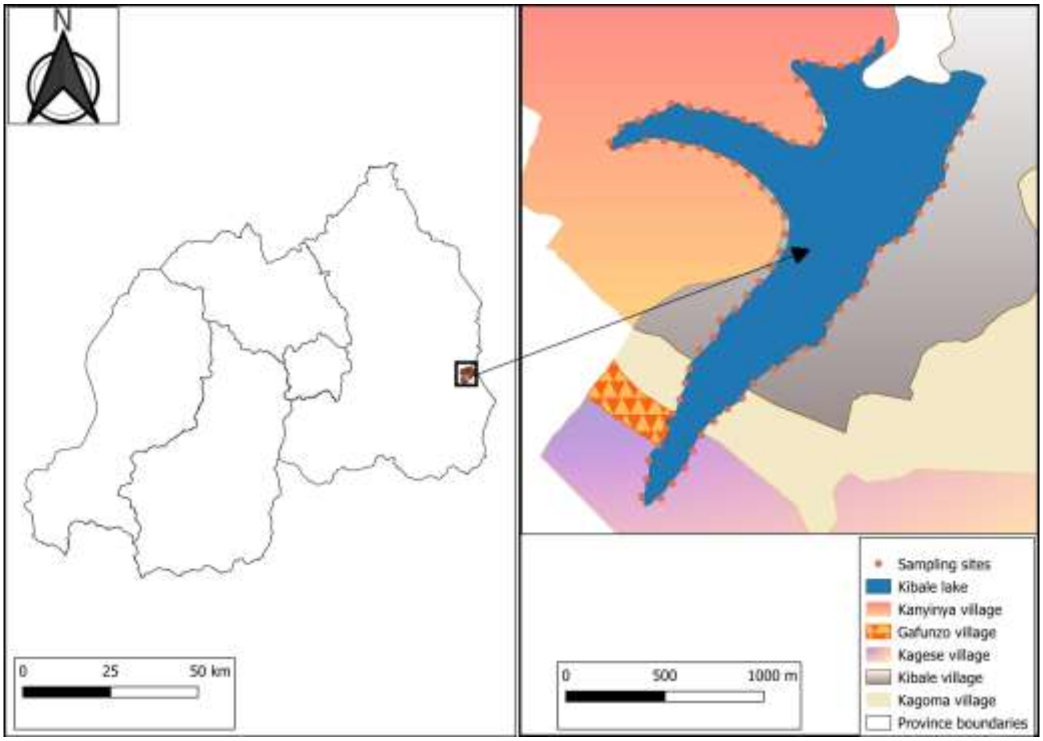

Figure 1: Map of Rwanda showing the five provinces of Rwanda, with the study site (Lake Kibare) located in the Eastern Province. Each point on the map inset represents a sampling site. Map designer: T. Hagenimana

3.2. Data Collection

3.3.Vegetation and land use survey in the riparian zone

To assess restoration of the riparian zone of Kibare Lake, vegetation was sampled within the riparian zone along 79 transects established perpendicular to the shoreline. Transects were 200m apart along the shoreline and the entire riparian zone was covered. The plots were placed from edge into uplands along the perpendicular transect. The first plot was placed in 3 meters from the lakeshore and another plot was placed in 3 meters from the first one and the last was placed in 3 meters from the second one. This means that along each transect which is perpendicular to the waterline, a circular plot was in every 3 meters. This approach ensured vegetation sampling at different distances from the shoreline to determine whether there is a change in plant community composition with distance from the lake. In total, I sampled in 237 circular plots of five meters radius. In each 5m radius circular plot, I recorded trees and shrubs. I also laid four small quadrants of one-meter square in each circular plot randomly to sample terrestrial herbaceous vegetation. In total, I sampled herbaceous vegetation in 948 one-meter square quadrants.

In each quadrant I estimated the percentage of the soil cover and recorded any sign of soil erosion in the area. Presence of soil erosion was determined by assessing the degree of soil erosion in each one-meter square quadrant. This was determined according to the criteria developed by Kosmas et al. (2014), specifically (i) the existence and percentage of eroded spots, (ii) the degree of exposure of the parent material on the soil surface, and (iii) the presence of gullies. From the observations and based on the methods developed by Kosmas et al. (2014), five classes of erosion were noted: (1) no erosion (no eroded soil surface, no parent material exposed and no gullies in a quadrant), (2) slight erosion (1-20 % of eroded soil surface, no parent material exposed and no gullies), (3) moderate erosion (21-50% of eroded soil surface, with or without the presence of exposed material and gullies), (3) severe erosion (51-80 % of eroded soil surface, with some spots where the parent material is exposed and observable gullies), and (5) very severe erosion (81-100% of eroded soil surface with exposed parent material and observable gullies).

Trees and shrubs were identified to species level, counted, and recorded during sampling. Herbs were assed using the presence/absence techniques for specific species. The abundance of each species was not recorded due to the time constraints. All species that were difficult to identify in the field were collected, pressed, and transported to the National Herbarium of Rwanda for further identification. After identification, specimens were procced and preserved in the National Herbarium of Rwanda. GPS coordinates were recorded at each sampling site for mapping. I also recorded each land use type in the riparian zone by transect walking. When land use was agriculture, I recorded the crop type. To determine the potential of every tree species to enhance climate change resilience, I consulted the guidebook entitled “Ecosystem-based Adaption guidelines for climate resilient restoration of savannahs, wetland and forest ecosystems of Rwanda” (REMA, 2019d). I also reviewed different books to find out whether a given species is native or exotic in the area.

3.4. Focus group discussion

To understand the perception of local communities to the riparian zone and its ecosystem services, I conducted a focus group discussing with local farmers and fishermen. Farmers selected for the focus group were recruited based on the criteria that they had land in the riparian zone before it was transferred to the public land status by the Rwanda Ministerial Order N°007/16.01 of 15/07/2010 determining the length of land on shores of lakes and rivers transferred to public property. Fishermen were selected among the people who go in the lake for fishing. These people depend almost entirely on fishing, and they have almost the same level of income. People belonging to fishing cooperatives with the capacity to hire other people were excluded in the study with the assumption that they have diversified livelihoods, and hence they can gain additional income outside of fishing. Participants of this study were selected randomly among other farmers and fishers.

I held focus groups with men and women separately because when mixed with men, women are less likely than men to speak (Dyer, 2018). Each focus group had seven people in total, and I held three focus groups with 21 people in total. All three focus group discussions took place near the lake, at houses of the fishing cooperative (Cooperative Icyerekezo de Pêche de Ndego) in March 2020. Each focus group discussion took two hours.

During the discussion with local farmers and fishermen, the main purposes were to understand the climate context in the study area as perceived by the farmers and fishermen, to identify the perceptions about the importance of the riparian zone in climate change resilience and the riparian zone management. The purpose was also to ask participants about current and anticipated climate hazards, which may affect local communities and existing coping strategies. Further, the focus group discussion explored the different ways that people were using the riparian zone before and after restoration. Participants in the focus groups were able to express themselves about what they lost economically due to riparian zone management measures and what they think about benefits of these riparian zone management measures. During the discussion, I raised the question around my themes of interest and heard everyone's view on the subject. I allowed everyone to speak and come to the consensus. I recorded the discussion using the phone's recorder and took notes.

Chapter 4. Data analysis

Vegetation data were analyzed by calculating the species abundance for trees and shrubs. Regarding terrestrial herbaceous vegetation, I calculated the frequency of every species sampled. Throughout this document, the word "frequency" is used to mean the number of quadrants where a given species is present among 948 quadrats I sampled. I calculated the relative abundance by calculating the percentage of the abundance of every species in comparison to other herbaceous species sampled. Regarding the soil erosion, I calculated the mean percentage of eroded soil in all quadrants sampled. Focus group discussion data were translated from Kinyarwanda to English (see questions asked in the attached in appendix). Data were then analyzed though the "Content Analysis Method' around different themes of interest. Themes included local livelihoods, role of the riparian zone management, climate change hazards in Ndego sector and coping strategies to adverse impacts of climate change.

Chapter 5. Results

5.1.The state of Lake Kibare Riparian Zone

During plant sampling, 17 tree and 12 shrub species distributed in 21 families were recorded in the riparian zone. Fabaceae family is the most represented, with five species. The second most represented family is Anacardiaceae which is represented by three species. Bignoniaceae, Euphorbiaceae and Rutaceae are represented by two species while all other remaining families are represented by one species. Among species sampled, bamboo (*Bambusa ssp)*, Silky Oak

(Grevellia robusta) and fruit trees such as mango (*Manguifera indica),* papaya (*Carica papaya)* and Avocado (*Persea americana)* were planted by REMA under the riparian zone restoration activities through the LDCFII Project. *Acacia kirikii* is the most abundant tree species recorded (Table 1). This species was mostly recorded in the eastern part of the lake which is used for pastoralism and hence, less disturbed compared to other parts of the riparian zone. Other tree and shrubs species recorded include *Vernonia amygdalina, Senna spectabilis, Solanum betaceum* and one invasive species such as *Lantana camara*. Erosion was recorded in 0.2 % of all sampled 948-quadrants and it was classified as "Slight erosion". The mean percentage of vegetation ground cover in all quadrants sampled is 68%.

Table 1: Tree and shrub species present in Lake Kibare riparian zone

No	Scientific name	Venacular name	Familly	RA (%)	Origin	Invasive? Yes/No
1	*Acacia kirkii*	Umunyinya	Fabaceae	18.0	Indigenous	No
2	*Grevillea robusta*	Gereveriya	Proteaceae	16.1	Exotic	No
3	*Bambusa vulgaris*	Umugano	Asteraceae	10.0	Exotic	No
4	*Vernonia amygdalina*	Umubiririzi	Compositae	8.4	Native	No
5	*Carica papaya*	Ipapayi	Caricaceae	8.0	Exotic	No
6	*Senna spectabilis*	Gasiya	Fabaceae	5.0	Exotic	No
7	*Moringa oleifera*	Moringa	Moringaceae	4.6	Exotic	No
8	*Solanum betaceum*	Ibinyomoro	Solanaceae	4.2	Exotic	No
9	*Ricinus communis*	Ikibonobono	Euphorbiaceae	3.4	Native	No
10	*Lantana camara*	Umutamutamu	Verbenaceae	3.1	Exotic	Yes
11	*Mangifera indica*	Umwembe	Anacardiaceae	2.7	Exotic	No
12	*Persea americana*	Avoka	Lauraceae	2.3	Exotic	No
13	*Caesalpinia decapetala*	Munyegereze	Fabaceae	1.5	Exotic	No

14	*Grewia similis*	Umukoma	Malvaceae	1.5	Native	No
15	*Haplocoelum foliolosum*	Umushami	Sapindaceae	1.5	Native	No
16	*Rhoicissus tridentate*	Umuhurura	Vitaceae	1.5	Native	No
17	*Elaeis guineensis*	Umukindo	Arecaceae	1.1	Native	No
18	*Albizia petersiana*	Umumeyu	Fabaceae	0.8	Native	No
19	*Erythrina abyssinica*	Umuko	Fabacease	0.8	Native	No
20	*Olea europea*	Umunzenze	Oleaceae	0.8	Native	No
21	*Ozoroa insignis*	Umukerenke	Anacardiaceae	0.8	Native	No
22	*Rhus natalensis*	Umusagara	Anacardiaceae	0.8	Native	No
23	*Carissa spinarum*	Umushubi	Apocynaceae	0.4	Native	No
24	*Citrus sinensis*	Icunga	Rutaceae	0.4	Exotic	No
25	*Clerodendrum johnstonii*	Ikiziranyenzi	Lamiaceae	0.4	Native	No
26	*Markhamia lutea*	Umusave	Bignoniaceae	0.4	Native	No
27	*Markhamia obtusifolia*	Igikori	Bignoniaceae	0.4	Native	No
28	*Sesbania sesban*	Umunyegenyege	Fabaceae	0.4	Native	No
29	*Vepris nobilis*	Umuzo	Rutaceae	0.4	Native	No

RA: Relative abundance (The percent number of individuals of a given species relative to the total number of organisms present)

Table 2: Tree/shrubs species present in the Lake Kibare riparian zone with climate resilience and livelihood role

No	Scientific name	Life form	Climate resilience role	Livelihood role
1	*Acacia kirkii*	Tree	-Shading	Construction material
2	*Grevillea robusta*	Tree	-Shading -Windbreaking -Live fence - Soil fertility	-Construction material -Fuel wood -Timber
3	*Bambusa vulgaris*	Shrub	-Live fence -Insect and disease resistance -Shore protection -Soil stabilization -Wind breaking	-Construction material -Handcraft
4	*Vernonia amygdalina*	Shrub	-Soil fertility -live fence	-Traditional medicine -Bee forage -Handcraft -Fuel wood
5	*Carica papaya*	Tree	NA	-Edible fruit -Traditional medicine
6	*Senna spectabilis*	Tree	-Shading -Wind breaking	-Traditional medicine -Fuel wood

				-Ornamental -Bee forage -Construction material
7	*Moringa oleifera*	Tree	-Shade -Soil stabilization -Wind breaking	-Traditional medicine -Fodder -Bee Forage
8	*Solanum betaceum*	Shrub	NA	Edible fruits
9	*Ricinus communis*	Tree	NA	-Traditional medicine -Fuel wood
10	*Lantana camara*	Shrub	Live fence	-Traditional medicine -Fodder -Ornamental
11	*Mangifera indica*	Tree	-Shading -Soil stabilization -Wind breaking	-Edible fruits -Traditional medicine -Bee forage -Construction material
12	*Persea americana*	Tree	-Shade -Soil stabilization -Wind breaking	-Edible fruits -Fuel wood -Oil for cosmetic industries -Fodder -Construction material
13	*Caesalpinia decapetala*	Tree	-Live fence	Ornamental
14	*Grewia similis*	Shrub	-Insects and disease	-Bee forage

			resistance -Soil fertility -Shading -Soil stabilization	-Handcraft -Fuel wood -Fodder -Traditional medicine
15	*Haplocoelum foliolosum*	Tree	NA	-Construction material -Timber -Bee forage -Edible fruits
16	*Rhoicissus tridentata*	Shrub	- Drought tolerant - Deciduous	Traditional medicine
17	*Elaeis guineensis*	Tree	NA	Oil production
18	*Albizia petersiana*	Tree	-Soil fertility -Shading -Soil stabilization	-Construction material - Handcraft -Fuel wood Timber -Traditional medicine
19	*Erythrina abyssinica*	Tree	-Live fence -Insects and disease resistance -Soil fertility -Shading -Soil stabilization	-Bee forage -Handcraft -Fuel wood -Ornamental -Timber -Traditional medicine

20	*Olea europea subsp Africana*	Tree	NA	Fuel wood
21	*Ozoroa insignis*	Tree	-Drought resistance -Insects and disease resistant -Shading	-Bee forage -Fuel wood -Traditional medicine -Timber
22	*Rhus natalensis*	Shrub	NA	Traditional medicine
23	*Carissa spinarum*	Shrub	NA	Traditional Medicine
24	*Citrus sinensis*	Tree	NA	-Edible fruit - Aromatic oil -Traditional medicine -Fuel wood
25	*Clerodendrum johnstonii*	Shrub	NA	Traditional medicine
26	*Markhamia lutea*	Tree	-Insects and disease resistance -Soil fertility -Shading -Soil stabilization	-Construction material -Handcraft -Fuel wood
27	*Markhamia obtusifolia*	shrub	-Drought resistant -Insects and disease resistant -Soil stabilization	-Bee forage -Fuel wood -Ornamental

				-Traditional medicine -Timber
28	*Sesbania sesban*	Shrub	-Soil fertility -Shading -Live fence -Wind breaking	-Bee forage -Handcraft -Fodder -Fuel wood -Traditional medicine
29	*Vepris nobilis*	Shrub	NA	-Fuel wood -Timber -Traditional medicine

Fifty-one herbaceous species were found in the riparian zone and most of these species are common to disturbed areas. These include *Bidens pilosa, Digitalia scrarum* and *Pinesetum crandestenum.* Table 3 shows herbaceous species found in the riparian zone of Lake Kibare.

Table 3: Herbaceous species found in the riparian zone of Lake Kibare

No	**Scientific name**	**RF (%)**	**Origin**	**Occur in disturbed areas? Yes/No**	**Family**	**Reference for main habitat**
1	*Bidens Pilosa*	11.22	Indigenous	Yes	Asteraceae	(Kewat & Jha, 2018)
2	*Oxygonum sinuatum*	8.06	Indigenous	Yes	Polygonaceae	(Bussmann, 2015)
3	*Commelina africana*	7.07	Indigenous	Yes	Commelinaceae	(Bussmann, 2015)
4	*Pentas zanzibarica*	6.93	Indigenous	Yes	Lamiaceae	NHR information
5	*Cyperus latifolius*	4.64	Indigenous	Yes	Cyperaceae	(Kewat & Jha, 2018)

6	*Euphorbia heterophylla*	4.57	Indigenous	Yes	Euphorbiaceae	(Kewat & Jha, 2018)
7	*Cyperus rigidifolius*	4.53	Indigenous	Yes	Cyperaceae	(Bryson & Carter, 2014)
8	*Galinsoga parviflora*	3.99	Indigenous	Yes	Asteraceae	(Bailey, 1914)
9	*Ocimum gratissimum*	3.83	Indigenous	No	Lamiaceae	(Bussmann, 2015)
10	*Justicia flava*	3.72	Indigenous	No	Acanthaceae	NHR information
11	*Commelina bengalensis*	3.42	Indigenous	Yes	Commelinaceae	(Kewat & Jha, 2018)
12	*Eleusine indica*	3.16	Indigenous	Yes	Poaceae	(Kewat & Jha, 2018)
13	*Indigofera arrecta*	3.09	Indigenous	Yes	Fabaceae	(Bussmann, 2015)
14	*Pennisetum purpureum*	3	Exotic	Yes	Poaceae	(Cutts et al., 2011)
15	*Emilia caespitosa*	2.91	Indigenous	Yes	Asteraceae	NHR information
16	*Alternanthera sessilis*	2.61	Indigenous	Yes	Amaranthaceae	(Kewat & Jha, 2018)
17	*Ocimum lamifolium*	2.38	Indigenous	No	Lamiaceae	NHR information
18	*Conyza sumatrensis*	2.29	Indigenous	Yes	Asteraceae	(Santos et al., 2014)
19	*Digitaria ternate*	2.17	Indigenous	Yes	Cyperaceae	(Ricardo, 2002)
20	*Sida cordifolia*	1.92	Indigenous	Yes	Malvaceae	(Hayashi et al., 2013)
21	*Cyathula uncinulata*	1.75	Indigenous	Yes	Amaranthaceae	(Mosango and amaganda, 2001)
22	*Digitaria scalarum*	1.59	Indigenous	Yes	Poaceae	(Chandler, 2016)

23	*Striga hermonthica*	1.09	Indigenous	Yes	Orobanchaceae	(Jamil et al., 2012)
24	*Hyparrhenia filipendula*	1.06	Indigenous	No	Poaceae	NHR information
25	*Sesamum angolense*	0.97	Exotic	No	Pedaliaceae	NHR information
26	*Dischoriste perrottetii*	0.92	Indigenous	Yes	Acanthaceae	NHR information
27	*Leucas martinicensis*	0.67	Indigenous	Yes	Lamiaceae	(Tesfaye, 2018)
28	*Hyparrhenia rufa*	0.48	Indigenous	Yes	Poaceae	(Starr et al., 2006)
29	*Crotalalia incana*	0.42	Indigenous	No	Fabaceae	
30	*Hygrophila auriculate*	0.28	Indigenous	Yes	Acanthaceae	(Vijayakumar et al., 2006)
31	*Pennisetum clandestinum*	0.25	Exotic	No	Poaceae	(Bussmann, 2015)
32	*Cynodon dactylon*	0.21	Indigenous	No	Poaceae	(Kewat & Jha, 2018)
33	*Leonotis nepetifolia*	0.21	Indigenous	No	Lamiaceae	(Labiatae et al., 1979)
34	*Clerodendum johnstonii*	0.16	Indigenous	No	Verbenaceae	NHR information
35	*Convolvulus arvensis*	0.16	Indigenous	Yes	Convolvulaceae	(Kewat & Jha, 2018)
36	*Sonchus oleraceus*	0.14	Indigenous	Yes	Asteraceae	(Bussmann, 2015)
37	*Desmodium gangeticum*	0.12	Indigenous	No	Fabaceae	(Suman et al., 2015)
38	*Hibiscus diversifolius*	0.09	Indigenous	Yes	Malvaceae	NHR information
39	*Bidens stepia*	0.05	Indigenous	Yes	Asteraceae	NHR information

40	*Embelia schimperi*	0.05	Indigenous	No	Primulaceae	NHR information
41	*Hygrophila spiciformis*	0.05	Indigenous	Yes	Acanthaceae	NHR information
42	*Kalanchoe beniensis*	0.05	Indigenous	No	Crassulaceae	NHR information
43	*Laggera crispata*	0.05	Indigenous	No	Asteraceae	NHR information
44	*Sporobolus pyramidalis*	0.05	Indigenous	No	Poaceae	NHR information
45	*Aloe macrosiphon*	0.02	Indigenous	No	Aloeaceae	NHR information
46	*Cyperus dives*	0.02	Indigenous	Yes	Cyperaceae	(Bryson & Carter, 2014)
47	*Cyperus papyrus*	0.02	Indigenous	Yes	Cyperaceae	(Kewat & Jha, 2018)
48	*Datura stramonium*	0.02	Indigenous	No	Solanaceae	NHR information
49	*Momordica foetida*	0.02	Indigenous	No	Cucurbitaceae	NHR information
50	*Melinis repens*	0.02	Indigenous	Yes	Poaceae	(Lonsdale & Lane, 1994)
51	*Tagetes minuta*	0.02	Indigenous	Yes	Asteraceae	(Bussmann, 2015)

NHR: National Herbarium of Rwanda

5.2. Climate change hazards in communities around Lake Kibare and coping strategies

In this study, I discussed with male farmers, female farmers and fishers who are all males. Seven persons with almost the same level of income composed each group. The average age for all participants was 40 years. Except fishermen, all focus group participants were subsistence farmers. Key livelihood activities in the community are fishing, agriculture and livestock farming. Both male and female do agriculture while only male do fishing.

Participants in the focus groups mentioned climate hazards, which affect their livelihood. They said that unusual winds and droughts have been affecting their community in recent years. Droughts particularly reduced agricultural production in many years since 1997 when the area was first inhabited. Participants in all three groups reported that in 2016 and 2018 the local communities in this area suffered from food shortage due to drought, and the government provided maize, beans and cooking oil to all the people in Ngego sector until the following harvesting time. In these two years, the government also provided seeds of maize and beans. Participants mentioned that unusual winds also destroyed about 10 houses in Ndego sector in 2018. However, they added that the rain has been very heavy in the period prior to the field work for this study (March, 2020) and this affected negatively the production of cereals, while banana, cassava and maize were affected positively.

The focus group participants mentioned coping strategies they have developed to adapt to climate hazards. All respondents explained that good business relationships between them and Tanzanians help them cope with food shortage problems in the area. They also mentioned that they water their crops especially vegetables when the field is not far from the water source. Finally, they mentioned that they leave the area and go to work for money somewhere else.

Participants also mentioned measures they believe would help them to be more resilient to climate change effects. These include planting more trees in the riparian zone, including agroforestry trees like *Grevillea robusta* and *Senna spectabilis* which resist to droughts, introducing irrigation systems, establishing tree nurseries where people may voluntarily take seedlings to plant on their lands, and planting indigenous trees such as *Haplocoelum foliolosum* (Umushami) and *Ficus thonningii* (Umuvumu). They also suggest that the government can help them remove water hyacinth (Eichhornia crassipes) in the lake, even though they are not sure if climate change may be playing a role in the spread of this invasive species in the lake. Participants suggested that it would be useful to punish people who burn papyrus around the lake. They also suggested that the government can strengthen the collaboration with local community in the riparian zone management.

5.3. Community attitudes and perceptions about riparian zone management

When asked about how the riparian zone was used before its designation to a conservation area, they responded that agriculture and pastoralism were taking place there. The riparian zone was also the most preferred area for these two economic activities because of its proximity to water. This allowed them to water crops and provide water to cows easily. When asked how they benefit from the riparian zone since the LDCFII project started, the farmers (both men and women groups) did not identify any direct benefit. The fishermen’s group reported that fish production has increased due to the riparian zone management.

In relation to climate change resilience, participants reported that the riparian zone buffers the uplands from floods and erosion, protects from water level fluctuations in the lake, improves water quality especially when the lake is flooded and provides spawning areas for fishes. Participants mentioned that riparian zone protection improves water quality of the lake, which they depend on for drinking water, cooking, washing clothes and other household activities. They also mentioned that the riparian zone acts as buffer zone for wild animals such as *Syncerus* *caffer* (African buffalo). They mentioned that these wild animals graze in the riparian zone instead of raiding their crops.

Both male farmers and fishermen reported that the riparian zone is worth protecting and no other activities should take place there except conservation activities. Women had a different idea. They expressed the belief that it is good for them if they are allowed to go back in the riparian zone to do their activities as usual. One female in the group responded, "*We were relying totally on the land in the riparian zone but now, we are suffering from food shortage. We wish to go back in the riparian zone to cultivate because trees can grow even better if we are there because we cannot harm them. We can only cultivate around them"*. According to the women's focus group discussion, cultivating in the riparian zone can be a good way to control weeds which limit the growth of trees planted in the riparian zone for restoration.

Chapter 6.Discussion

Acacia kirkii was the most dominant species among trees sampled in study. This species was mostly recorded in the eastern part of the study area which is occupied by pastoralism. Since this eastern part is less disturbed in comparison to the remaining part, the vegetation present in the eastern part of the lake should indicate how the riparian zone would look in the absence of heavy human disturbance of the riparian zone. Acacia is one of the species naturally occurring in savanna woodland (Scharfstein & Gaurf, 2013; Weare, 1971). In Rwanda, Nduwayezu et al. (2009) found this species in Nyagatare district of the Eastern Province, and in Akagera National Park at 1300-1450m altitude in forest galleries.

Grasses were the most abundant terrestrial vegetation found in the riparian zone, which are not common in natural and undisturbed savanna habitats (Scharfstein & Gaurf, 2013). Most of these grasses are weeds occurring on annual croplands with either single or multiple crop species. These findings are consistent with those of Maitima et al. (2009), who showed that more than 90% of herb species present in crop land are weeds. Some weeds such as *Galinsoga parviflora* are not found in intact ecosystems since they are not shade tolerant (Smith, 2018), and their presence in the riparian zone suggests land degradation.

The word "Weed" is generally defined as a plant growing where it is not wanted or a plant growing in human-disturbed habitats (Bussmann, 2015). This is especially the case for agricultural ecosystems and gardens. However, this definition is not appropriate in natural resource management context since one species may be wanted by one person but unwanted by another one. For example, plants growing in a field or pasture may be unwanted by a farmer but they may be wildflowers to other people (Radosevich et al., 2007). Research also shows that weeds are used as traditional medicine in Kenya (Bussmann, 2015). For this reason, this study defines weeds as "plants that alter the structure of natural communities, interfere with the function of ecosystems, or have negative effects on humans, agriculture, or other societal interests" (Bryson & Carter, 2014).

Theoretically, selected native grasses, shrubs or tree species compose the riparian zone. Three distinct parallel zones with different vegetation types are needed for a healthy riparian zone to withstand climate hazards and sustain biodiversity (Goodwin et al., 1997). From the lakeshores to upland, zone 1 should be a narrow, undisturbed forest with native trees to protect lakeshores and the aquatic environment (Figure 2). Zone 2 should be an area with a managed woody and shrubby vegetation for sequestering sediment and nutrients from upland runoff (Figure 2). Zone 3 should be an herbaceous filter strip for dispersal of incoming upland surface runoff, some sediment and nutrient deposition (Inamdar et al., 1999).

Soil erosion was observed in only 0.2% of all quadrants. This is maybe associated with the presence of many plant species in the riparian zone. The mean percentage ground cover for all quadrants sampled is 68%. Groundcover vegetation provide mechanical soil protection by increasing rain water infiltration, reducing splash erosion and sheetwash erosion (Duan et al., 2020). This idea is also supported by Ghahramani et al. (2011) who showed that the ground cover is associated with splash and sheetwash erosion. Ghahramani et al. (2011) revealed that the ground cover prevent splash and sheetwash erosion.

In the current study, respondents reported that agriculture and pastoralism were taking place in the whole riparian zone, and it was the most preferred land for these activities because it is close to water. In addition, all farmers indicated they receive no direct benefit from maintaining the riparian zone for conservation. This may be a reason why many people in the community have not stopped using the land in the riparian zone. The main assumption of the TPB described in the introduction is that people behave according to beliefs that they hold (Beedell & Rehman, 1999). In line with this, Fielding et al. (2005) suggested that it is beliefs about the benefits of riparian zone management that are critical for influencing the adoption of riparian zone management measures. Therefore, the efforts to promote riparian zone management need to demonstrate benefits of riparian zone management before the majority of concerned people are willing to adopt this good practice (Fielding et al., 2005). People in the community need to believe there is a benefit from protecting the riparian zone from certain activities in order to change their behavior towards the riparian zone.

Particularly, women participants have shown that they want to continue agriculture in the riparian zone. In contrast, male farmers reported that it is fine to abandon the riparian zone for conservation activities. Women are often more concerned with household food security than men (Gathagu et al., 2014). This may be especially true in rural communities. Most of the time, men engage in seasonal migration for off-farm jobs, particularly in Africa and Asia, leaving women with subsistence farming (Villamor et al., 2014).

The difference in responses from men and women may be also explained by the fact men may have other livelihood alternatives apart from agriculture. Men are more likely to engage in off-farm jobs than females (Xie et al., 2019). In Ndego sector, commercial activities, and migration in search for jobs are possible alternatives to agriculture for men. Also, the access to new technology and information is highly gendered in general, with most of the related initiatives targeting men (Polyn & Maetala, 2011). Bernadette & Rebecca (2008) pints out that men are more likely to get training in new technologies in comparison to women which positions men to get the off-farm jobs that use advanced technologies.

Even though farmers did not report any direct benefits from the riparian zone, possibly due to the lack of knowledge about this zone, some regulatory services such as flood mitigation, erosion control and water quality improvement, were mentioned. Farmers also mentioned the role of the riparian zone as a buffer and a wildlife habitat. However, these ecosystem services are not enough to motivate positive behavior in riparian zone management. Research shows that usually, farmers value provisioning ecosystem services more than any other kind of services (William, 2018). For example, farmers almost always asked what they would be given in return for adopting conservation agriculture in Zambia even though they were fully aware of regulatory ecosystem services (Nyanga et al., 2011). Unfortunately, incentives provided to local farmers deter farmers from understanding climate change issues because they associate sustainable conservation practices with direct gains. A continued climate change education with local farmers should go along with incentives if incentives are provided. These climate change communication platforms can provide a means through which perceptions of farmers can be integrated into climate change adaptation projects (Nyanga et al., 2011).

All participants in the focus group discussion rated droughts and floods as the main climate hazards affecting the community. Particularly, the year 2020 was characterized by relatively more rain than in previous years according to the focus group participants. In May 2020, the whole riparian zone was flooded. Since the local community depends on the Kibare Lake for water provisioning for household activities, the riparian zone has the potential to improve water quality (Scharfstein & Gaurf, 2007), thus helping them cope with water scarcity issues. Participants are also aware of this important ecosystem service.

Chapter 7. Conclusion and recommendations

The study revealed that 29 tree and shrub species are present in the riparian zone. These species play the role in climate change resilience to the riparian zone ecosystem and improve livelihood of people around the lake. Soil stabilization, improving soil fertility, providing the shade and wind breaking are main climate resilience roles identified. However, agriculture and pastoralism activities are still occurring in some parts of the riparian zone. This is maybe because the local community are not aware of provisioning services the riparian zone can offer if it is well managed. Participants in this study are fully aware of regulatory ecosystem services the riparian zone can provide but these are not enough to motivate them to leave the area. This study recommends livelihood diversification to reduce their dependance on the riparian zone, increased access to clean water for local people and awareness raising about the importance of appropriate riparian zone management.

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Appendix 1: Questions asked during the focus group discussion

Section 1: Lake and riparian zone ecosystem services before and after the riparian zone restauration

1.1. How do you benefit from the lake and its riparian zone? List all benefits you can remember.

1.2. How were you benefiting from the lake and its riparian zone before it is restored?

1.3. Do you think it can help reduce climate change effects?

1.4. How do you think it must be managed?

Section 2: Climatic information

2.1. What are climate hazards have you observed in the past 10 years

2.2. What are climate hazards do you observe now?

2.3. How intense are they (Rate them from one to four, where 1 means more intense and 4 means less intense)?

2.3. How do you expect these climatic hazards you mentioned to change over time (Will they increase in intensity or decrease?)

2.4. How do you think these hazards will affect you directly or indirectly?

2.4. How these extreme events affect you personally?

2.5. How do you respond to these extreme events when they occur?

Section 3: Key resources in the community and livelihood context

a. What are main income generating activities in this area?

b. Who does each of these activities? (only men, women or both)

c. Who supports you in each of these activities to maximize the income?

d. What are challenges do you face in your income generating activities

e. What are key livelihood resources to you?

f. Who can access these resources?

g. Who controls these resources?

h. How do you think climate hazards will affect these resources?

i. What are coping strategies to reduce these impacts

j. How sustainable do you think are they?

k. Would you propose other strategies to cope with climate change impacts?

Appendix 2: Data sheet for grasses sampling

Date	**Transect #**	**Plot #**	**Subplot #**	**Species name**	**Ground cover %**	**Erosion sign**

Appendix 3: Data sheet for trees and shrubs sampling

Date	Transect #	Plot #	Species name	DBH	Height	GPS Point #