Research Report

Role of agroforestry on the restoration of Akanyaru, Murago and Cyohoha ecosystem complex to enhance resilience of riparian communities to climate change effects

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Executive Summary

Climate change variability and environmental degradation has resulted to wetlands degradation, and this has created various problems around wetlands ecosystem. Wetlands have been degraded and loses the potential ecosystem functioning and ecosystem services. To solve the problem the government of Rwanda has started to claim the wetlands and apply mainly restoration by using Agroforestry. This is the case for example of Akanyaru, Murago and Cyohoha wetlands to promote the socio-economic development of the communities around the wetlands. However, wetlands are vulnerable parts of our natural ecosystem where floods, drought and infertility of the soil are one of the most problems occur. This research aimed to assess the role of agroforestry on the restoration of Akanyaru, Murago and Cyohoha ecosystem complex to the resilience of its riparian communities to climate change effects in Eastern province of Rwanda and present the data from farmer-to-farmer interview, focus group discussion, field observation from transects walk and Soil carbon stock measurement. Results showed that local people are benefiting and having access to enough water and fish production with *Grevellea robusta* and *Phoenix reclinata* which were used as dominated tree in the buffer zone and farmland with also two agroforestry system used are Agrosilvicultural system and silvopastoral is mainly found. Farmers perception on effective wetland use and management suggested mostly wish that irrigation should be promoted with addition trees for the best of their future for replacing the dead trees. The carbon stock is still low compared to area with no plantation. Control area shows high carbon stock due to uncultivated area, and indigenous trees. This research demonstrated how agroforestry systems and practices is able to bale with both adaptation and mitigation strategies and may lead to different ways to stabilize food security for the poor farmers despite the fact to contribute to climate change mitigation.

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Chapter 1. Introduction

1.1. Background of the study

Climate change has implications for Africa which are highly distinctive. Its climate is likely to be affected more severely than that of other regions. in Africa many of the adverse consequences are already apparent (Collier, Conway, & Venables, 2008).

Climate fundamentally controls the distribution of ecosystems, species ranges, and process rates on Earth. Ecosystem patterns and processes, such as rates of primary productivity or input–output balance of chemical elements, respond in complex ways to climate change because of multiple controlling factors. For example, whether a forest is a carbon (C) source or sink depends on the balance of primary production and ecosystem respiration, processes that respond to different drivers (Grimm et al., 2013).

Ecosystem degradation is one of the major degradations of social, environmental, and economic sustainability, it has pushed many countries as well as Rwanda to invest in restoring the land in their priorities. More energies are required to keep vital ecosystems and sanctuary resources and more production. Degraded ecosystem requires various approaches where agroforestry is one of the best that restore, and conserve also ensure livelihood improvement. Agroforestry practices has the capacity to reorient degraded land to sustenance livelihoods, increase food security, restore ecosystem services, Agroforestry is expected to deliver very useful functions and increase the quality of the habitat a well as benefiting agriculture for the future upcoming (Dosskey et al., 2012).

Physical changes in ecosystems – for instance, changes in thermal stratification patterns in lakes and oceans, flood and drying regimes in streams and rivers, or intensification of the hydrologic cycle across large basins – lead to changes in ecosystem structure and function that have economic and human consequences (Grimm et al., 2013), the CO2 increase are subjecting most riparian ecosystems and increasing water temperatures and air linked with human caused climate change to high degree. Moreover, with changes in precipitation patterns and global warming. Rainfall and heavy precipitation are rising in most regions' and is happening in catchments between upland and lowlands influences. On bigger scales, riparian ecosystem roles comprise the regulation of climate, water, sediments, nutrients, soils and topography, and food production and transfer among food webs (Capon et al., 2013).

Many factors are affecting wetlands and riparian such as construction, filling, channelization, various activities, and other considerable modification. Wetlands and riparian areas, in agricultural sector are obstructed by grazing and elimination of natural vegetation and replacement of perennial cover and annual crops. All of this impacts the water quality improvement functions of wetlands and riparian zones and this may result to NPS problems (U.S. Environmental Protection Agency, 1993).

Wetlands are able to perform important role in hydrological and biogeochemical cycles and deliver a varied assortment of ecosystem goods and services to humankind. Wetland has the capacity to retain water during dry season and keeping the water table high and moderately stable, as it has a potential to regulate a microclimate, Wetlands provide many ecosystem services that are critical to reduce the vulnerability of communities to climate change in general and to extreme weather events in particular. Wetland has a fundamental ecological function that plays an irreplaceable role in serving biological survival and human development (Bi et al., 2019).

Riparian zones are impacted by agricultural activities, urbanization, climate change, alteration, urbanization, pollution, and biological invasion. Riparian zones deliver health and sustainability for the function of ecology and offer servicer to river. That should be well maintained for the best management and its conservation. Riparian zone has qualified to be the best way to sustain and improve wetlands conditions by serving as a barrier between agricultural fields and waterways (Singh, Tiwari, & Singh, 2021).

Livelihood system and human developments is affected by climate change and its associated problems, human responses to environmental change are too often expressed as generalized inputs within prescriptions for resilience. resilience in policymaking has often been based on the ability of systems to bounce back to normality, drawing on engineering concepts. This implies the return of the functions of an individual, household, community, or ecosystem to previous conditions. Crucially, resilience is increasingly providing an integrative 'boundary concept' that brings together those interested in tackling a range of shocks and stresses, including food security, social protection, conflict and disasters (Tanner et al., 2015).

Nowadays, there is a concern on land degradation and changes in climate parameters that led to changes in ecosystem functions. These changes affected local people in different ways, including water and food scarcity (Mbow et al., 2014). The same case with Rwanda to solve this problem, there was a need to look for solutions that can reduce land degradation and climate change effects. In this line, agroforestry was considered as one of the solutions due to numerous benefits local people can gain from it, including improvements in food availability, income generation, and mitigation to climate variability and climate change. Agroforestry produces fuel wood, fodder and fruits, construction, materials, medicines, fibers, and serve as the habitat for other biodiversity (Sitaram, 2015).

Restoration should consider various areas such hydrology as it is complicated at both local and watershed scale. Planning must be putted into consideration during restoration and enhancement of the project implementation, problems and opportunities should be considered (Endreny, 2005).

Restoration is very important to produce social benefits with addition to biophysical improvements, with a various opportunity in experimentation to provide the interactions between human and non-human within the ecosystem. And this has putted restoration to the level can restore the ecosystem to the maximum human benefits while minimizing involvements of much energy, and this has leads to the longest term results for favorable condition to climate from the restoration site (Casagrande, 1997).

Agroforestry is a land use system that plays an important role in conserving soil and water. The management of buffer zone has become a concept of integrated development approach to nature conservation for ecological importance and addressing the development issues of the surrounding area. Buffer zone agroforestry has the potential to deliver tree products in a sustainable way and improving local agriculture (Wolde, 2017). Agroforestry offers environmental services such as biodiversity, water quality and soil fertility improvements. In Rwanda, agroforestry is also the inclusion of trees with food crops or pasture where it provides great potential of providing sustainable income to farmers, sequester carbon, and production of bioenergy**.** Agroforestry has been identified as the effective strategy to support smallholder farmers to adapt to climate change in addition with the situation of agricultural challenges facing Rwanda. Climate change is negatively affected food production by increasing climate variability and agroforestry is way to spread to farmers the production of firewood, building material, fruits and other tree products (Stainback, Masozera, Mukuralinda, & Dwivedi, 2012)

Agroforestry as the integration of trees, agricultural crops, and/or animals into an agroforestry system can enhance soil fertility, reduce erosion, improve water quality, enhance biodiversity, increase aesthetics, and sequester carbon (Garrett et al. 2009). This are ecosystem services and environmental benefits that agroforestry can provide.

Agroforestry system potential to sequester carbon always depend up on the type of system used, the composition of the species, the age of component species with the geographic location, environmental factors and its management practices the potential of agroforestry to rise the fertility is always enhancing and maintaining for a long term in a sustainable way. The combination of trees and crops sometimes can biologically fix nitrogen. Agroforestry contributes to biodiversity conservation through different ways, which are: agroforestry provides habitat for species that can tolerate a certain level of disturbance, Agroforestry aids preserve germplasm of sensitive species; Agroforestry assists to reduce the rates of conversion ,Agroforestry provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and Agroforestry helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat.

Agroforestry also contributes to the provisioning services that include reduction in wind speed, control of erosion, and enhancement of soil quality. Agroforestry systems increase nutrient inputs in soil through nitrogen fixing trees and nutrient uptake from deep soil horizons. Agroforestry decreases nutrient leaching through tree root and mycorrhizal systems, and works as a salvage of nutrients through the breakdown of litter, pruning and root residues (Sitaram, 2015). According to the same author, agroforestry is also appreciated to be an intermediate and a combination of agricultural and forestry that create a combined, assorted, and fruitful land use systems. By considering the benefits of agroforestry, Rwanda, through Rwanda Environmental management authority, decided to do the restoration of Akanyaru, Murago and Cyohoha ecosystems.

Restoration was found to be very important in different studies where restoration program with an ecosystem approach through best Management Practices (BMPS) is useful in correcting point and non-point sources of pollution and its requires profound planning, authority and funding along with financial resources and active involvement from all levels of organisation this is very important in innovating and inaugurating the restoration programs (Ramachandra & Ahalya, 2001)

Integrated adaptation and mitigation activities are intended to bring resilience of land-use systems to the impacts that climate change effects at the same time reducing the negative and unstainability impacts to human activity resulted from climate change. To find out these activities require differents analysis that takes in consideration the potential of a land use system for carbon sequestration, The capacity to increase the resilience of that system to climate change and the capacity of local communities to involve and maintain the project and being aware from the benefits they would derive from it (Matocha et al, 2012)

1.2. Problem statement

Climate changes have caused many problems including drought, flooding and soil infertility. Agroforestry has been addressed as one of the potential solutions of this problem to different areas worldwide (Jose, 2009), agroforestry has been used during restoration. Due to its potential role by increasing soil fertility, improve water quality, and develop biodiversity interactions (Jose, 2009), agroforestry has been used during restoration .The same problem happened in Bugesera district within the area surrounding the ecosystem complex of Akanyaru, Murago and Cyohoha where problems related to climate change created serious problem for the riparian communities living around the ecosystem complex. These problems were decreased precipitation, drought, and flood events. Agroforestry system has been used to restore the wetlands for building the resilience of riparian communities to these effects, and it has been seen as the potential solution to resolve these effects and maintain benefits that local people could gain from these ecosystems. Benefits for the local people include provision of financial benefits to landowners and farmers for land-use practices that maintain environmental services. In some areas in the tropics, agriculture land is being affected and becoming unprofitable to local people. In such circumstances restoration must focus on restoring ecological functionality to flexible landscapes thereby improving the livelihoods of local people at the same time improving global goods and services such as biodiversity conservation and carbon sequestration, this has been approved that amount of carbon equivalent to 20 years' worth of deforestation is deposited in agroforestry systems (Sahoo, Wani, Sharma, & Rout, 2020)

Rwanda climate is tropical, where local population suffer from dry period that often happen periodically. Although agroforestry is capable to deal with those challenges faced by local people and has the potential to be an operative approach to support smallholder farmers to adapt to climate change (To et al., 2011). Agroforestry buffer zone has the potential of hindering many disasters faced by the surrounding populations and the ecosystems by maintaining biological diversity as well as improving living standard of riparian communities (Orsdol, 2018)

From the time of restoration activities in 2017, nothing is known about how the restoration of Akanyaru, Murago and Cyohoha ecosystems using agroforestry has contributed to climate mitigation and improved livelihoods of the local people. This research provided prior information about how climate effects were reduced and how local people are benefiting from the restored ecosystems, with the main purpose to suggest sustainable management of Akanyaru, Murago and Cyohoha ecosystems because Agroforestry is able to build livelihood resilience to the impacts of climate change for smallholder farmers.

1.3. Objectives of the study

1.3.1. General objectives of the study

The main purpose of the research was to assess the role of agroforestry on the restoration of Akanyaru- Murago-Cyohoha ecosystem complex to enhance resilience of riparian communities to climate change.

1.3.2. Specific objectives of the study

Specifically, this research aimed to:

1) Investigate agroforestry systems, practices and species used to restore Akanyaru, Murago and Cyohoha ecosystems,
2) Evaluate the benefits that local peoples gain from the restored ecosystems compared to the time before the restoration,
3) Evaluate changes in levels of climate change effects before and after the restoration
4) Evaluate the perceptions of local people towards sustainable monitoring of the restored ecosystems

1.4. Research questions

1) What are the agroforestry systems used to restore Akanyaru, Murago, Cyohoha ecosystems?

2) What are the benefits that local people gain from the restored ecosystems compared to the time before the restoration?
3) What are changes in levels of climate change effects before and after the restoration?
4) What are the perceptions of local people towards sustainable monitoring of the restored ecosystems?

Chapter 2. Literature review

Ecosystem services are well defined as “the situations and progressions through which natural ecosystems, and the species that make them up, withstand and accomplish human life (Sharma et al., 2007). Nowadays, there is a high population growth that increases the pressure on the natural resources through the over exploitation and extraction of the natural resources to sustain daily livelihoods. Land degradation is still classified as one of the key drivers of ecosystem change, and hence climate change. As a consequence, millions of people liable on forests and tree resources for their survival have turned out to be more vulnerable due to the effects of climate change and climate variability (Sharma et al., 2007).

Developing countries are suffering from climate change which leads to the negative impacts. Global conventions are not effective enough to stop the growth of atmospheric greenhouse gases (GHG) concentrations and there has been little attention given so far by policymakers to the relationship between climate change and the conservation and wise use of wetlands. According to the IPCC Second Assessment Report, changes in climate will lead to an intensification of the global hydrological cycle and could have major impacts on regional water resources even though wetland ecosystems offer important ecological functions (Wetland restoration,October199 Collection).

Ecosystem and local climate will change and are very aggressive to biota and human livelihoods and Local climates and terrestrial ecosystems will change, even though food, fiber, climate, environmental services. Even as climate changes, food and fiber production, environmental services and rural livelihoods must improve, and not just be maintained.

Agroforestry is one the good example of a set of innovative practices that are considered to enhance productivity in a way that contributes to climate change mitigation through carbon sequestration that is able to deal with the negative facts of climate change conditions (Verchot et al., 2007)

2.1. Ecosystem services definition and concepts

Ecosystem services are the profits individuals get from ecosystems and are co-produced by the connections among ecosystems and humanities. Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods, and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

Many years ago, agroforestry was endorsed as a very important land use method for dealing with conflict goals of agriculture production and environmental stewardship in southern Africa put reference .Human always hang on the nature of the environment properties like nutrients cycling, clean water and soil formation, this is due to the ecosystem services resulting from agroforestry which grouped into four categories (1) provisioning services (2) regulating services, (3) supporting services and (4) cultural services (Agroforestry and Ecosystem Services)

2.2. Biodiversity and Ecosystem Services

Biodiversity is connected to ecosystem facilities over a diversity of mechanisms working at diverse spatial scales (Mace et al. 2012). Biodiversity normalizes the state, the duties and in numerous cases the permanency of ecosystem processes essential to maximum ecosystem service. Components of biodiversity are also faster and direct collected to meet people's quantifiable needs and are also appreciated by humanities for their non-tangible donations to well-being, for instance to psychological healthiness, identity of the people and the advantage it can be for upcoming generations.

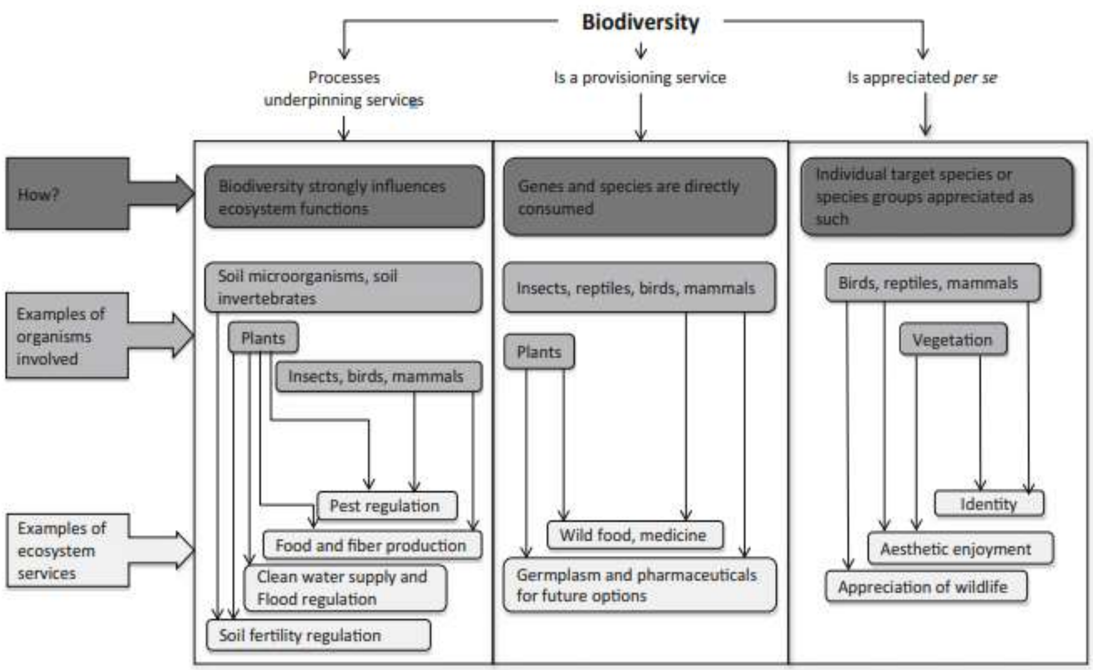

Figure 1: Sowing relation between biodiversity and ecosystem services

2.3. Key Ecosystem Service Concepts

Civilizations are entrenched indoors ecosystems, liable on and prompting the ecosystem services they yield. The structures of ecosystems, such as species arrangement, tree cover or growth circumstances, temper the kind and degree of ecosystem services that can drift towards societies. Organization commands, technologies, as well as tenancy and admittance measures that temper the ways by which ecosystem services are shaped and profit societies.

In other arguments, ecosystem services effect from the acquaintances amid ecosystems and humanities, which composed form a social-ecological system. Two types of ecosystem services can be distinguished (MA 2005).

Provisioning services are the goods that can be removed and disbursed from ecosystems and are often appreciated in market. Amendable services are the profits resulting from ecosystem procedures that modify the situations. such as the control of climate, soil fertility or floods (Chicharo, Müller, & Fohrer, 2015)

2.4. Ecosystem based adaptation and climate change

2.4.1. Ecosystem based Adaptation (EbA)

2.4.1.1. Characteristics and definition of EbA

Ecosystem based Adaptation is a method of preparation and applying climate change adaptation bearing in mind ecosystem services and its practices for social welfare. EbA inspires the usage of external and local facts approximately ecosystems to categorize climate change adaptation approaches, make out the assortment of local conditions and makes an enabling situation for operative local adaptation and ecosystem management. EbA also prioritized natural resource conservation as one of the key principles which enhances effectiveness of adaptation (Doswald & Osti, 2011).

2.4.1.2. Links between ecosystem service and wellbeing.

Ecosystem services are the profits that society acquire from ecosystems. Including food, supply of water quality, regulation of disease and pests, recreation, medicinal substances and against natural disasters such as floods. Functioning and composition of ecosystem changes is affecting human wellbeing, Agroforestry is capable of delivering services like regulating, supporting, and provision services.(Lead et al., n.d.)

3. Agroforestry as a means for adaptation

Agroforestry systems and practices are able to sustain smallholder farmers through provision of means for diversifying production systems and increase variability in rainfall and temperature. Tree planting is very important in maintaining production in every condition whether and drier years. This is due to the fact of their deep roots which are able to explore a large soil volume for water and nutrients which is in high competition during droughts. Tree planting is also capable of reducing runoff and increasing soil cover and leads in increasing of water infiltration rate. Finally trees help in increasing of the soil porosity, and have advanced evapotranspiration rates than row crops or pastures and can thus preserve aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems.(Verchot et al., 2007)

Intergovernmental Panel recognized Agroforestry on Climate Change (IPCC) as one of the solutions to climate change. It has the ability for sequestering carbon and has the capacity to change and raise livelihood as it provides many choices and opportunities to farmers to raise production within farms and incomes. Agroforestry gives productive and protective roles including biological diversity, maintaining ecosystems heterogeneity, protection of soil and water resources, and terrestrial carbon storage and hence protects the natural environment. Due to its combination with other crops, agroforestry is appreciated to be the main instrument that can be used to assure food security, and hence contributes to poverty alleviation, through the enhancement of ecosystem resilience (Sharma, Xu, & Sharma, 2007) .

Agroforestry has become a based soil fertility replenishment in fertilizer trees and shrubs developed in the late 1980 in different regions comprising for example southern African countries as one of the answers to the decrease of soil fertility and low level of macronutrients in soil. The action consisted of planting faster growing and nitrogen fixing leguminous trees and shrubs, whose biomass production is quick and high, with a faster rate of decomposition, resulting in in the release of nitrogen for crop growth. This concerned leguminous trees for example, planted to capture atmospheric nitrogen and release it into the soil upon decomposition and subsequently nourish crops that are planted in the field (Ajayi et al., 2009).

Agroforestry has the most important contributions generally that respond to climate change through carbon sequestration by producing above ground the biomass. The analysis showed that around 1.1–2.2x1015 g of C could be removed from the atmosphere over the next 50 years if agroforestry systems are implemented at the global scale.

The average carbon storage by agroforestry practices, of which fertilizer trees is an integral part has been estimated as 9, 21, 50, and 63 mg of carbon per hectare in semi-arid, sub-humid, humid, and temperate regions respectively (Wise and Cacho, 2005).

The tree biomass and roots of agroforestry also provide favorable environments for soil microbes and fauna which in turn break down the biomass and release plant nutrients (Sileshi and Mafongoya, 2006). This diversity can, in time, provide ecological resilience and contribute to the maintenance of beneficial ecological functions such as pest control (Sileshi et al., 2005). In addition, agroforestry maintains soil quality. Research indicated that soil aggregation is higher in fertilizer trees/shrubs agroforestry systems and enhances water infiltration and water holding capacity (Phiri et al., 2003). Some agroforestry, such as Leucaena species for example, have effective control on soil erosion (Banda et al., 1994). The role of agroforestry on ecosystems and human well-being are summarized in the figure 2.

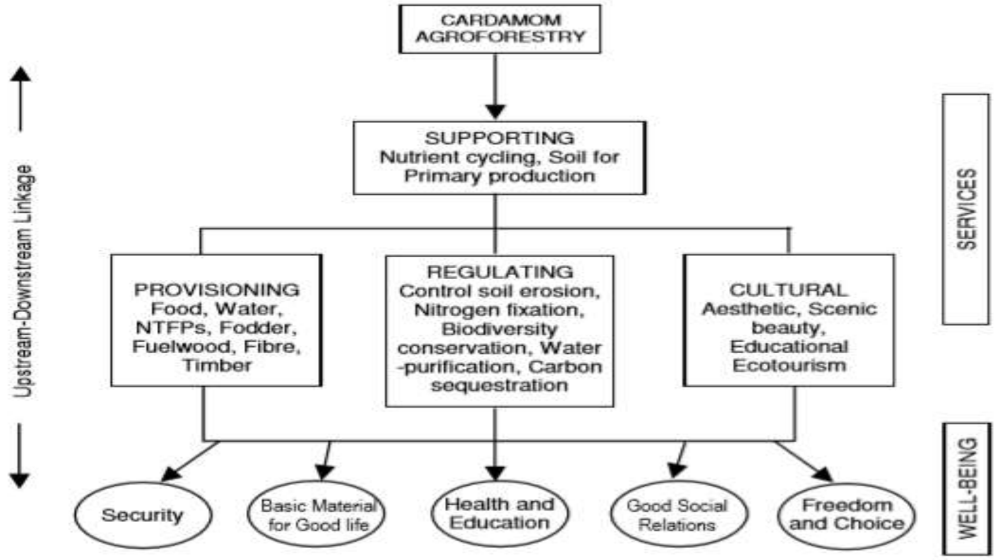

Figure 2: Role of agroforestry on human wellbeing and ecosystem services (Adapted from Sharma et al., 2007)

Reference to the above figure, restoration of ecosystems using agroforestry contributes to healthy ecosystems and improves the human wellbeing including security. They also provide food, water, fodder, fuel wood, fiber, and timber to local peoples. Further health ecosystems contribute to the aesthetic, beauty, educational and ecotourism that are beneficial for human beings. The agroforestry species that has been planted along the ecosystem up to the banks of Akanyaru Murago and Cyohoha are riparian vegetation. This riparian vegetation is extremely important because they can provide a number of benefits.

4. Agroforestry and resilience

Resilience has been considered as a connection within the social and ecological system that has been anticipated by Holling in 1973 as the solution that the system improves and springs back after the disturbance and shocks (Holling, 1973) in (Quandt et al., 2018). 40 years ago, in a variety of disciplines like engineering, disasters risk reduction and climate change adaptation and mitigation has been utilized (Carpenter et al.., 2013) in Quandt et al., 2018).

The resilience of a social-ecological system is then observed as either precise resilience to a certain disturbance or shock, or wide-ranging resilience which is the facility of a system to steer through an uncertain future Quandt et al., 2018). As the world problem is climate change and environmental degradation causing frequent drought and flooding in some parts of the world, agroforestry as the focused incorporation of trees into farmland and agricultural landscapes is the powerful solution. Agroforestry is capable of building resilience to livelihood to adapt for changes and the benefits include cash income, food, energy, medicine, construction materials, windbreaks, animal fodder, and soil and water conservation (Agroforestry and livelihood resilience)

5.Agroforestry as the viable Restoration option

The range of forestry options is increased due to agroforestry practices that might be the demand of the landowners. Agroforestry can be combined into farming lands and tailored through settlement and strategy to offer favorite mixes of production and conservation benefits. Agroforestry can be able to provide Profit potential which are competitive with agricultural crops and production forestry on marginal agricultural lands. ecosystem services may improve upcoming projections for agroforestry effectiveness.

Lack of familiarity and experience with agroforestry has hindered the adoption of agroforestry practices in many regions of the world and this has been pushed to have more options that landowners have to choose to, to increase the chance of discovering one that appeals to be good to the preferences of landowners. In this way agroforestry can enhance restoration functions and services (Dosskey et al., 2012)

6. Agroforestry system in Rwanda

Rwanda is a country of hills with less than 1500m of the altitudes in the eastern plateau but rising between 1500 and 2000m in the area of central plateau and in the west and north is higher. Rainfall patterns is affected by the variation in altitude., while the occurrence of volcanoes in the highlands and marshlands in the lowlands impacts soil fertility and slopes. Agriculture production has increased in Rwanda where the majority of the farmers derive their livelihood from the existence of agriculture to the small land less than 1 ha and the environment is affected day to day by several forms of land degradation, Reduction of organic matter, Soil erosion, Loss of soil nutrients, Loss of biodiversity, and soil acidification mostly by agriculture expansion. Hundreds of years, in

Rwanda agroforestry has been part of agriculture practices. One significant characteristic of traditional agroforestry is the preservation and managing of indigenous tree species, for social, economic, cultural, and ecological purposes. Since the 1970s, exotic agroforestry species have been announced among smallholder farmers by government and externally funded projects, while indigenous tree species have been less appreciated and devoted, at current, Rwandan agroforestry systems are conquered by a wide assortment of exotic and indigenous tree species that are appropriate for diverse agro-ecological zones(Iiyama et al., n.d.)

Chapter3. Material and methods

3.1. Site description

Akanyaru, Murago and Cyohoha ecosystem complex is located in Bugesera district, (Latitude: -2°15'0"Longitude: 30°7'59.98", Figure 2), at the altitude of 1344 m. The district is located between Nyabarongo and Akanyaru rivers and that are the major sources of water in the district. Bugesera is one of seven Districts of the Eastern Province of Rwanda. It covers a surface area of 1337 Km². The district is composed of 15 sectors, 72 cells and 581 Villages with a total population of 363,339 people, where 177,404 are males and 185,935 are females (NISR, 2012). Its population average per annual growth rate is 3,1%, with a population density of 282 people per kilometer square.

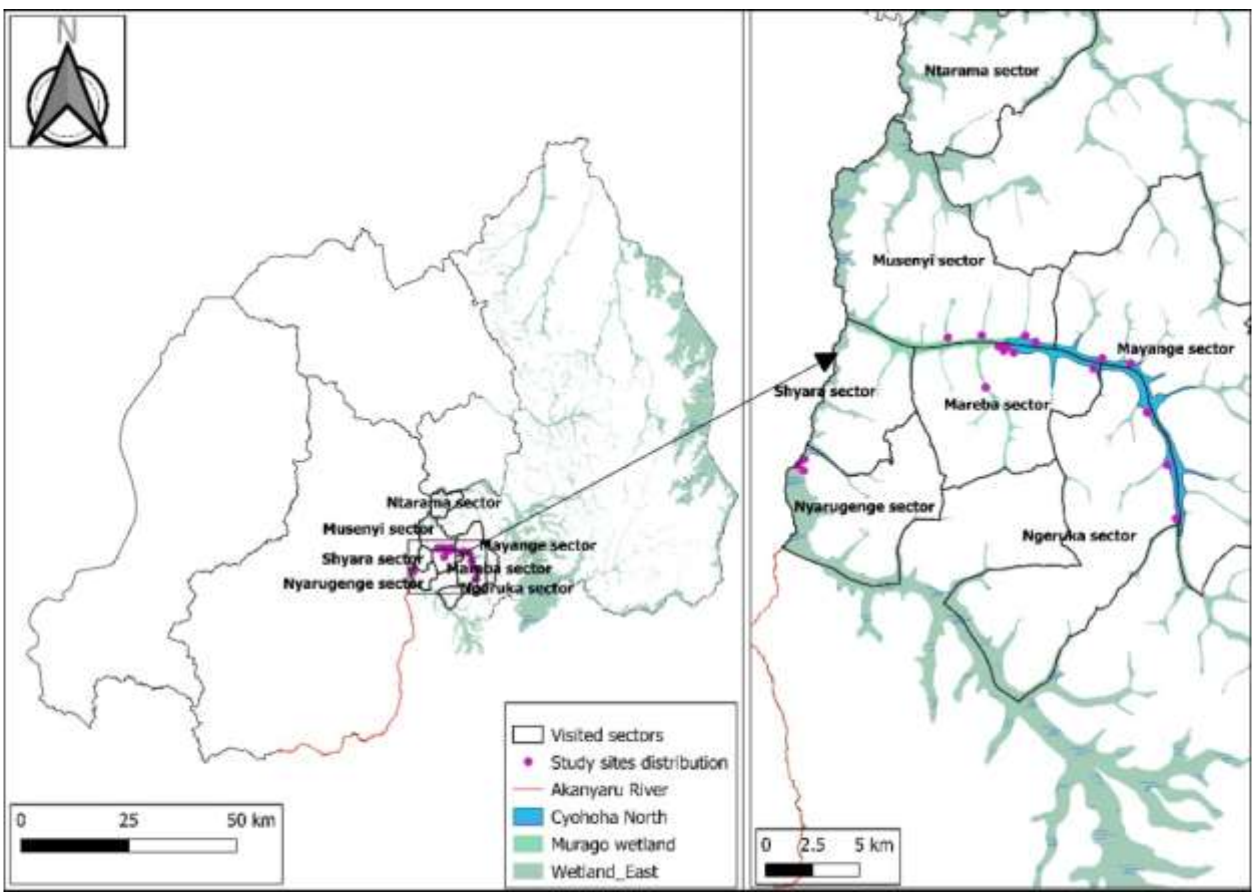

Figure 3: The map of Bugesera **district** (taken from Rainwater harvesting potential for crop production in the Bugesera district of Rwanda - Scientific Figure on Research Gate. Available from: https://www.researchgate.net/figure/Map-of-Bugesera-district-showing-its-location-in-Rwanda-and-the-sectors-that-form-the_fig1_283870873**.**

The relief is also constituted by a succession of low plateaus with hills and dry valleys. The district is equally rich in marshlands alongside rivers that cover an estimated area of 6,100 ha and are exploited at an average of 46.3% (CDP, 2006). The district has a dry climate with the temperature varying between 20°C and 30°C. The average temperature ranges between 26°C and 29°C. In the past years, the district was turning into a dessert zone. To solve this problem, natural resources, including wetlands were protected by the law, and this improved its climatic conditions. The vegetation is composed of acacia, euphorbia and the cactuses intertwined with gramineous and spiny bushes, as well as other rare species that support the bushes and trailing lianas.

3.2. Data collection methods

Data was collected using survey through interview, focus group discussion, field work observation and experimental measurement of soil carbon. For the focus group discussion and household survey, the participants were given a short introduction with explanation and the purpose of research to assure them that the information had kept confidential so that they feel free to give answers based on the reality. 177 Participants was selected purposively by using purposive random sampling where local people who lived in the area before and after the restoration was selected to participate in this research. Data which were collected through the household survey and focus group discussion helped us to collect data on:

1) The benefits that local peoples gain from the restored ecosystems before and after the restoration,
2) Changes in climate change effects before and after the restoration,
3) The perceptions of local people towards sustainable monitoring of the restored ecosystems.
4) And the agroforestry system, practices and species used during Restoration.

The last stage was about a transect walk in the study area to investigate physical data on agroforestry trees used for the restoration, and to approve information collected from group discussion and household surveys (Nabahungu and Visser 2013) in (Nsengimana, Weihler, & Kaplin, 2016). During transect walk, GPS data were collected and a map about the status of the Akanyaru, Murago and Cyohoha ecosystem complex were generated.

3.3. Soil sampling and analysis

As the field was big and complex, the field was divided into sampling zone with the same homogeneous and with the same management and cropping system by grouping the area of similar soil type, same crop and production characteristics. Each zone was sampled independently to reach the composite sample representing each zone**.** Twelve soil samples were taken with three additional sample representing the sample control. Loss on ignition method was used to determine the soil organic carbon found in the area of the study. This has been used based on the gravimetric weight change with the presence of high temperature. Two grams of soil were taken. Mass of crucible were measured, even both soil with crucible were also measured.

In different studies like soil science, Global climate change and in the ecology, the determination of soil organic carbon is very useful. Different method can be used but Loss on ignition has been suggested as the rapid, inexpensive and accurate method for assessing SOC. I collected fifteen samples from the ecosystem complex of Akanyaru, Murago and Cyohoha from 0-15 cm depth of the soil

3.5. Data analysis

The questionnaire data collected had the following main categories of information including agroforestry systems, practices and species used during restoration, the benefits that riparian communities gained after restoration compare before restoration, perceptions of riparian communities for sustainable monitoring of the restored area with organic carbon measurement using Loss on Ignition Method. Analysis using excel were used to generate the percentages and its frequency and are presented in the table and in the figures.

Chapter 4. Results

4.1. Demographic characteristics

4.1.1. Gender of the respondents

The results show that within gender the male is dominant with 52.26% whereas female is 47.7%, this show imbalance around the ecosystem complex and in participation in sustainable monitoring of the restored ecosystem, males were greater than females. The results demonstrated that women would have the same participation with men but still have some constraints such as scarcity of the resources and traditional cultural which led to the low contribution of women to the restoration activities.

4.1.2. Marital status of the respondents

The results indicate that 78.71% of the respondents were married, whereas single and divorced respondents took 1.94 each of them. The results showed that the riparian communities who have been affected by climate change variabilities are married. The results show that individual households' conditions impact the engagement in agroforestry practices as well as conservation and affects joining related meeting that leads to decision and management of ecosystem resources and discovered that agroforestry practices are related to marital status, gender, and education status.

4.1.3. Education level of the respondents

whereas the survey indicates their level of education shows 61.94 %attend primary education, 34.84% are literate, 2.58% are undergo secondary education, and 0.65 % has perform bachelor. The results reveals that the riparian communities who has been affected with drought and flood in the restored area mostly had primary education and this implies that low education level may affects the sustainability and implementation of the agroforestry system, practices and the treatments of the agroforestry species used. In the study area with the intergration of the treatment activity of the species used during restoration which has been reported by the riparian communities to be affected in various way.

Table 1: Demographic characteristics of the respondents

Demo Characteristics	**Demographic categories**	**Frequency**	**Percentage of Frequency**
Gender	F	74	47.74
	M	81	52.26
Level of education	Bachelor	1	0.65
	Secondary	4	2.58

	None	54	34.84
	Primary	96	61.94
Marital Status	Divorced	3	1.94
	Single	3	1.94
	Widow	10	6.45
	Widower	17	10.97
	Married	122	78.71

4.2. Occupation of riparian communities

The figure 3 below shows that 97.45% are farmers,1.91 % do fishing, and 0.64 are in teaching career. The results show that the respondents selected in the ecosystem complex made of seven sectors of Bugesera district indicate that riparian communities of the area, they are different major occupation that help in daily life this may impacts the perception of them to the sustainable monitoring of ecosystem due to the benefits they got from it. Consideration to value the role of agroforestry on the restoration, even though agroforestry sustainability is pushed by farmers-oriented factors that impact it in various way, they are number of challenges to the agroforestry practice comprise of absence of information, poor crop yield, and limited land.

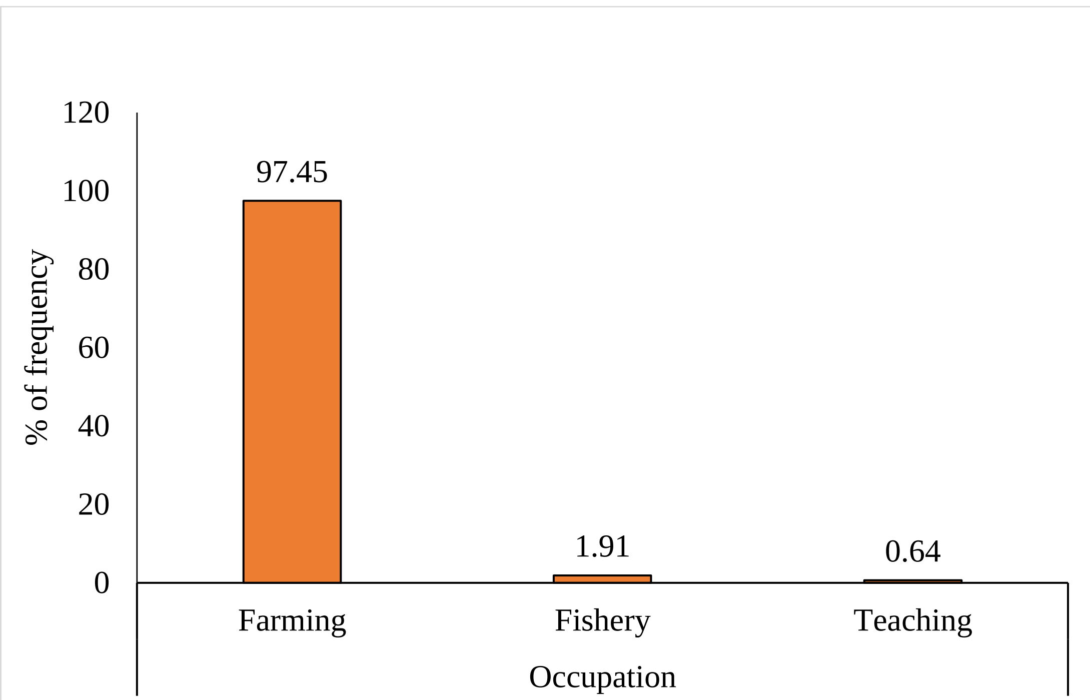

Figure 4: Major occupations of the riparian communities of the ecosystem complex.

4.3. Benefits that local peoples gain from the restored ecosystems compared to the time before the restoration.

The results indicate the benefits that riparian communities gained from the restored ecosystem are summarized below:

The survey showed that 46.8% are benefiting and having access to enough water,33.3% fish production,4.3% firewood,3.9 %agriculture production,3.9% ornamental material, 3.5 % sticks,2.2% bricks.0.9 % gain fresh air,0.9% fodder,0.4 % fruits. The trees are highly valued by farmers because of its various benefits from trees compensate for the loss of crop yield. Using Agroforestry system and practice to the study area of Bugesera after restoration has been contributing to numerous benefits to the riparian communities such as fishing, where some people depend on fisheries and fishing for survival. Well managed wetland helps in purification of water and filter waste this has contributed to the clean water of lake Cyohoha and Murago that are used by local people in their daily life, and this are mainly used for drinking, cooking, and cleaning needs. Due to the interview with riparian communities, they have mentioned that to restore the ecosystem complex, the trees used act as shelter during sun period, soil erosion has been reduced due to the increase of agriculture production.

Firewood from the trees used in restoration also help during period of lack of charcoal. During growing crops, trees used in agroforestry some use their branches as sticks when growing climbing beans. Water from the wetland they are also used when making bricks, some also of the trees are used as fodder production for livestock such as *Calliandra calothyrsus*. Using agroforestry in study area such as riparian buffer has been contribute to the high level of water increase and clean due to work as a means that combat non-point source of pollution from agriculture fields. This is the reason why water is the most highlighted as the first benefits that they recognize from the restored ecosystem compare before restoration where they always had polluted water. These results indicate that through agroforestry there is improvement in people's life.

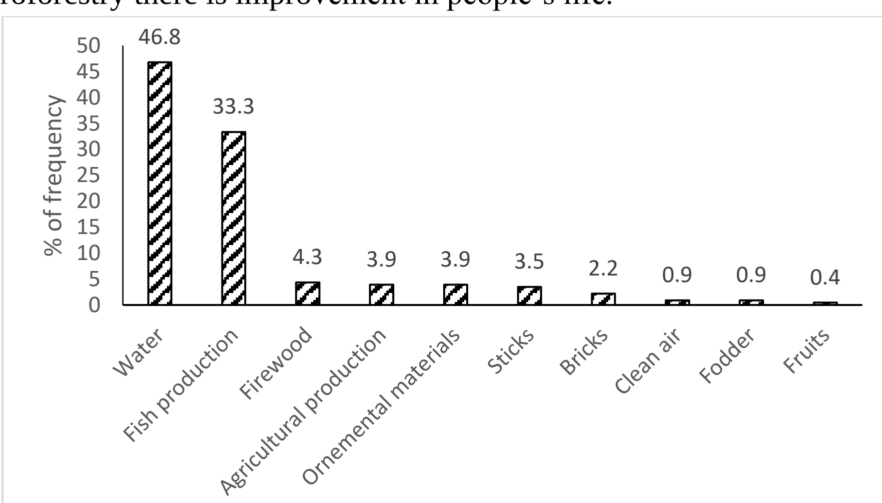

Figure 5: Indicate the benefits that riparian communities gain after restoration.

4.4. Agroforestry systems, practices and species used to restore Akanyaru, Murago and Cyohoha ecosystems.

The results indicate that 48% are dominated by *Grevellea robusta* and 0.42% are *Phoenix reclinata* which are least according to the respondents. The survey also indicates two agroforestry system found with 86.57% of Agrosilvicultural system and 13.42% of silvopastoral. Agroforestry practices, boundary planting is dominated with 66.49%, home gardens 1.55%, trees on rangeland 0.52%, scattered trees on farmland 31.44%. Agrosilvicultural systems was used to restore the ecosystem with Multipurpose trees on cropland, which some was used in way trees scattered, and other for boundaries in the buffer zone of Akanyaru, Murago and Cyohoha.

This Agroforestry system and practice used has positively affect the ecosystem and the livelihood development of the study area.

Differents tree species was used to restore the ecosystem which are *Grevellea robusta*, *Bambusa vulgaris*, *Acacia mearnsii*, *Calliandra calothyrsus*, *Pinus patula*, *Leucena leucocephala*, *Jacaranda*, *Cedrela serrata*, *Persea americana*, *Markhamia lutea*, *Maesopsis eminii*, *Phoenix reclinata*. In the study area differents agroforestry species has been used to restore Akanyaru, Murago and Cyohoha ecosystem complex to enhance resilience of riparian communities to climate change effects. Although drought and flood are more frequent, more severe, and longer lasting. These species are not yet having the positive impacts on the ecosystem, but some few benefits are gained by the riparian communities.

Agroforestry practices used in the ecosystem complex of Akanyaru, Murago and Cyohoha from the survey, the predominant respondents have mentioned boundary planting, and the scattered trees on farmland as agroforestry practices used during restoration. The results also show that the tree species that has mostly used during restoration is Grevellea robusta due to its rapid growth and is faster benefits.

4.5. Agroforestry system used in restoration

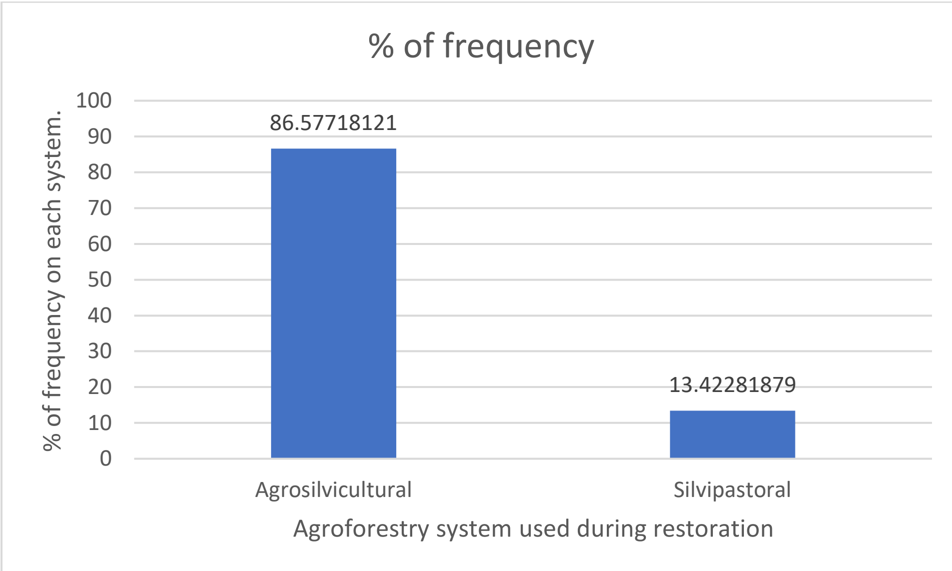

Figure 6: Agroforestry system used in restoration

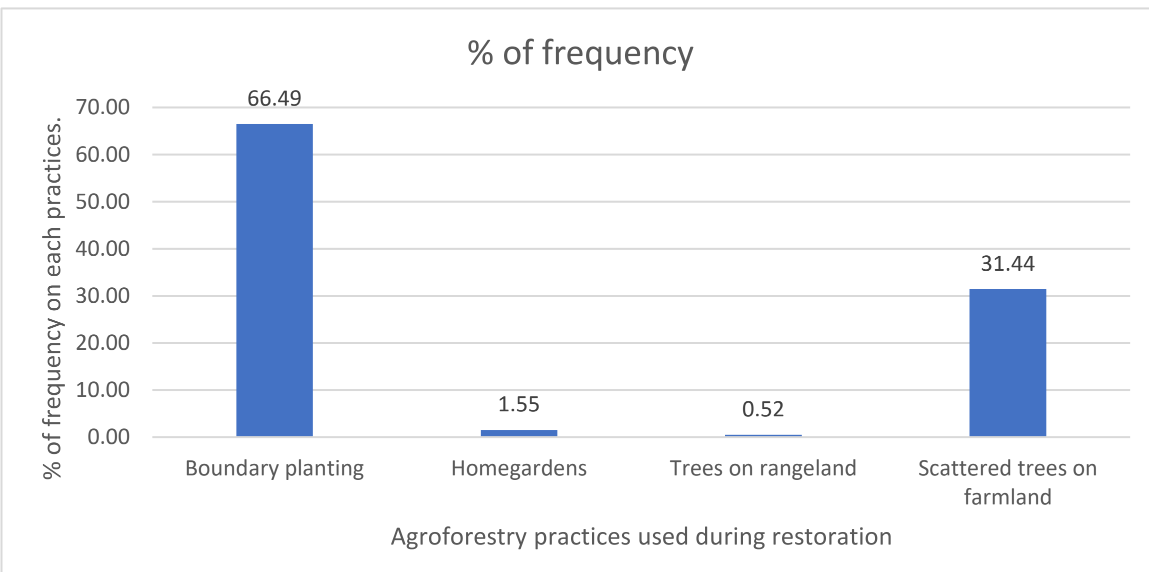

Figure 7: Various agroforestry practices used in restoration.

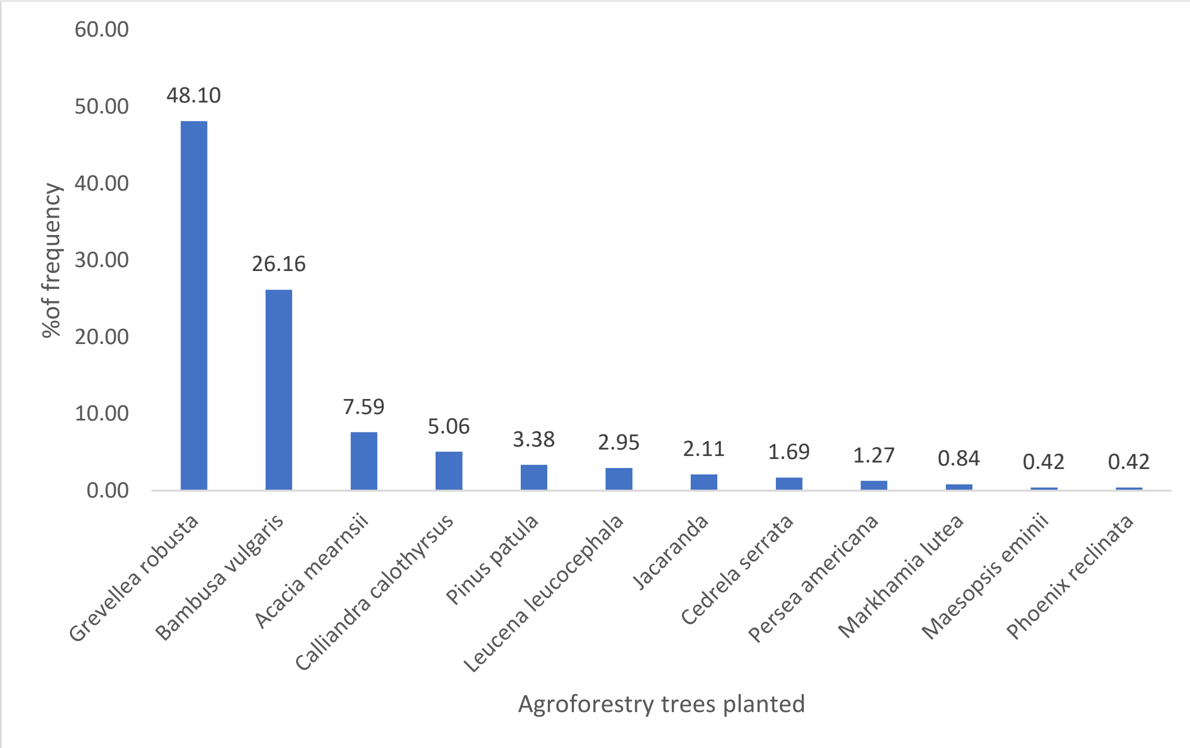

Figure 8: Different agroforestry species used in the restoration

4.6. Source of information on wetland use and Management

The results indicates that 12.9% get information from agronomist,5.7% are from farmer promoter,50% from local leaders, 31.4% from Rwanda Environmental Management Authority. Information on wetland use and management to the riparian communities and its effect to climate change effects is very important for sustainable management and development. This area suffers for a frequent drought and flooding. In the study area local communities had differents workshops with local authorities and Rwanda Environmental Management Authority to make them aware on why implementing Agroforestry activities to the buffer zone of the ecosystem complex which were obliged to take few meters to their land. Different activities are taking place around the wetlands, and we know that wetlands are vital in the fight against poverty and the preservation of biodiversity. Participation of everyone in the wetlands use and management will help in preventing floods by holding rainwater, stabilizing banks, and combating erosion by supporting plant life and providing resources to the local population and this can use to drive socio- economic development in more specific terms and providing the main source of income for local families.

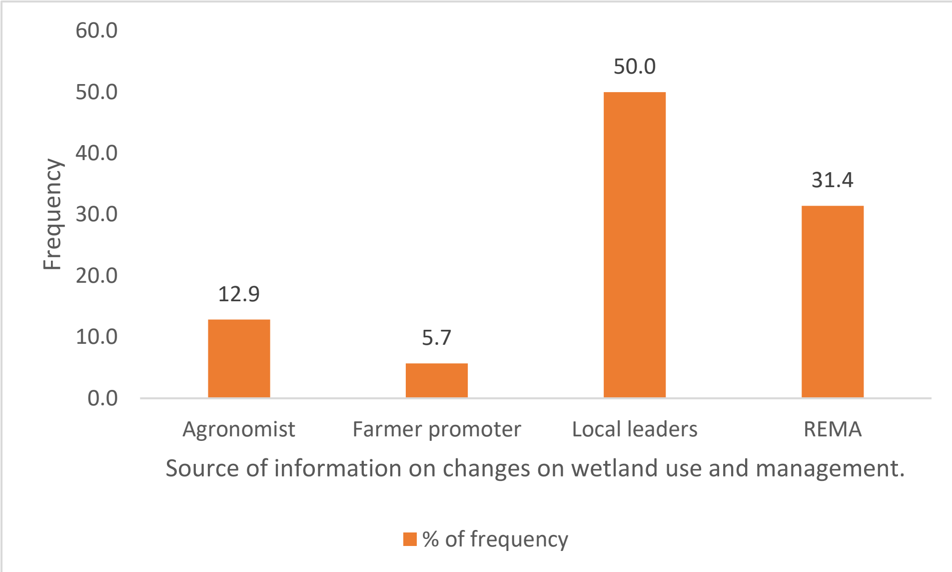

Figure 9: Source of information on wetland use and management

4.7. Satisfaction of wetland use, and management compare before restoration

The results indicate 24.2% agree ,23.6% disagree, 38.2 % strongly agree,14% strongly disagree. Information collected during Survey and focus group discussion about the satisfaction of the way the ecosystem complex is managed compare before restoration has shown that the total population are strongly agree with the management and has also satisfied by the activities done. Other remaining population are in negative way that are not satisfied by the way the wetlands are management compare before restoration. This comes up with the information and addressing the role of implementing the activities before starting.

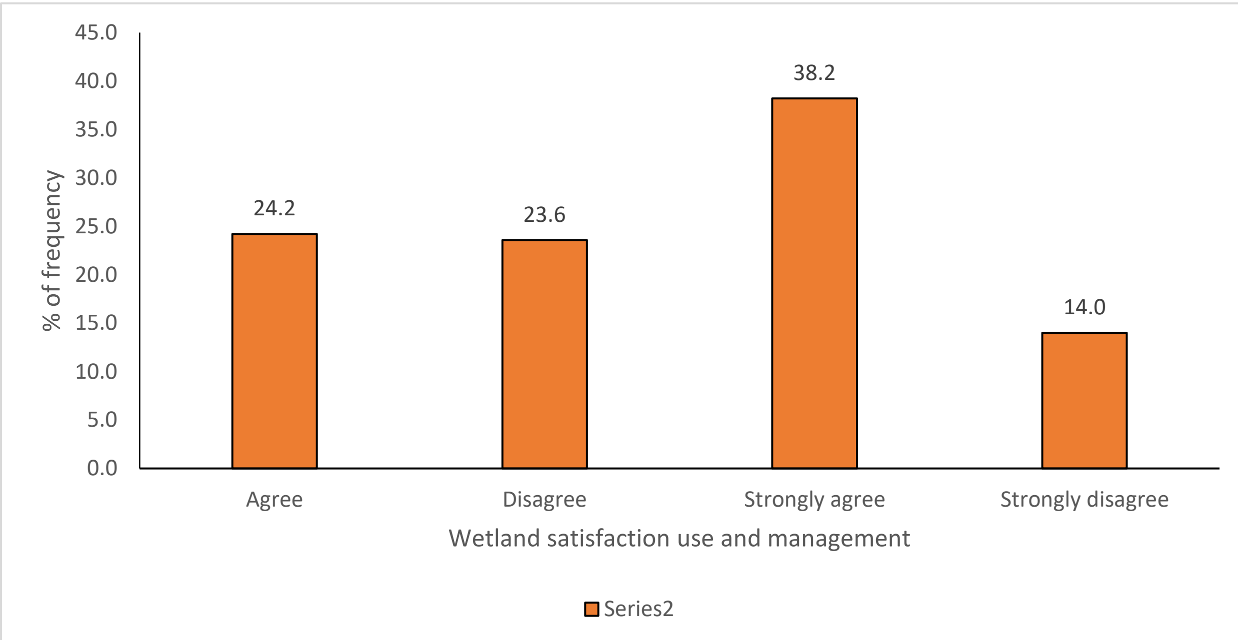

Figure 10: Level of satisfaction on wetland use and management

4.8. Range of population farmed in the ecosystem complex before and after restoration

The results indicates that 3.8 % have not been in the area before restoration even if they are by now, 96.2% farmed around the ecosystem complex before even after restoration. Time spent in the area for riparian communities has the great impact on the activities which took place in the area, this is the same as the study area of Akanyaru, Murago and cyohoha ecosystem complex.

Implementation of agroforestry to restore the ecosystem complex to enhance resilience of riparian communities, to change the area in a desired direction, community patterns have to be considered and have sufficient relationships that results to design proper management plans and this show that riparian communities are a typical good example because of their numerous interrelated systems. Human intervention who had and still having access to the ecosystem have been participated to the research.

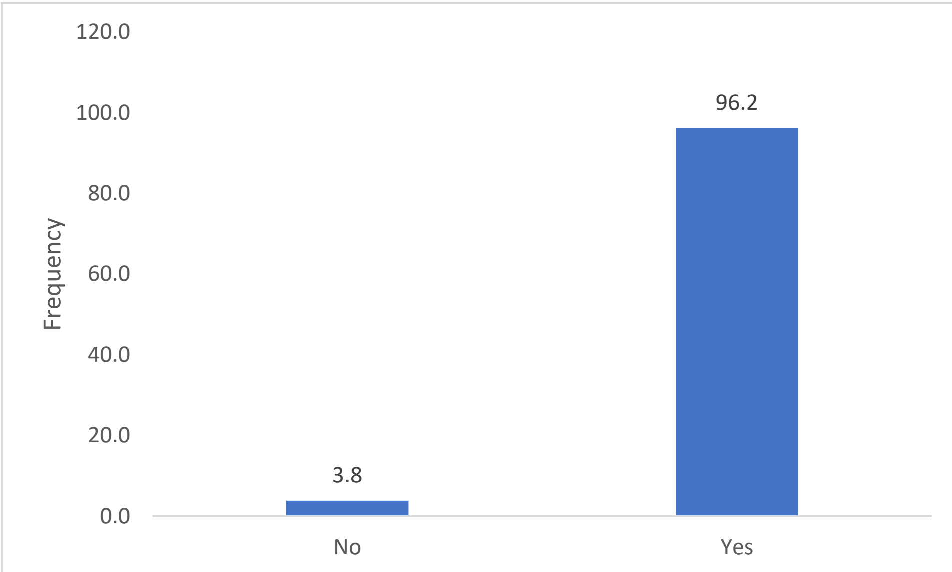

Figure 11: Range of population farmed in the ecosystem complex before and after restoration

4.9. Evaluation of changes in levels of climate change effects before and after the restoration

Restoration using agroforestry on the soil surrounding the buffer zone of the wetlands has decreased the degradation and increase the soil physical, chemical and biological conditions. The role of agroforestry systems and practice can bring favorable changes in all conditions. Data from household's survey of the study area interviewed has provided logical way how agroforestry has brought resilience to the riparian communities related to climate change effects. And this has both directly and indirectly bring local people resilience to the problem of flooding and drought. The respondents show that after restoration, due to the benefits they got from the restored area, Trees planted were used their branches as mulching, some were used as firewood, sticks for climbing beans, this one of the ways that restoration of the study area using agroforestry has brought resilience to climate change effects in terms of capital.

Table 2: Carbon analysis by loss on ignition

Site	Depth	Mean				SCS with corresponding control
		OM	OC	BD	SCS	
Murago	15cm	4.105	2.38	1.23	4.35	4.35±8.39
Cyohoha	15cm	5.59	3.24	1.09	2.92	2.92±7.81
Akanyaru	15cm	5.79	3.35	1.47	5.86	5.86±8.74

The results indicate that among soil sampled area with correspondence control the carbon stock is still low compared to area with no plantation. Control area shows high carbon stock due to uncultivated area, and indigenous trees we found in the study area. The area of restoration was not had trees and the one used for restoration are not yet provide the positive impacts. Potential sequestration of Carbon of agroforestry system has attracted worldwide attention resulting the gratitude of agroforestry as the mitigating strategy for greenhouse gas under the Kyoto protocol.

Table 3: Changes in level of rainfall in the study area from 1981-2015.

Average Rainfall from	**Nyamata (average)**	**Ruhuha (average)**	**Juru (average)**
1981-1985	2.62	1.83	3.06
1986-1990	2.57	2.55	3.17
1991-1995	2.38	2.13	3.24
1996-2000	2.81	2.14	4.03
2001-2005	3.03	2.02	3.97
2006-2010	2.7	2.09	4.3
2011-2015	2.19	1.82	3.78

The results indicate variability in rainfall data with each five years with low variability in temperature**.** Agroforestry system has been found to barrier the consequence of the dangerous weather in microclimate by decreasing the instabilities in both air and soil temperatures, humidity and responsible in decreasing wind velocity near the soil surface as, microclimatic variations in agroforestry systems also reduce soil moisture evaporation.

4.11. Changes in Temperature in the study area.

Climate patterns were analyzed using meteorological station data from 1983-2017 of monthly total maximum temperature, where there is occurrence of instability of temperature variation during period of study. This shows low impact of the agroforestry tree species to the study area

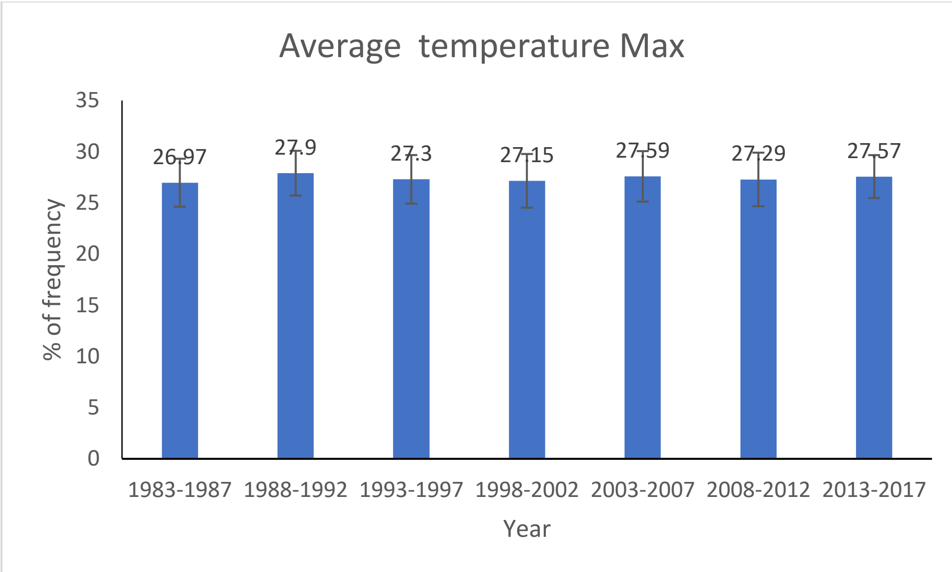

Figure 12: Changes in level of temperature of the study area from 1983-2017

Agroforestry offers microclimate improvement as it has a major impact on crop performance in agriculture production, agroforestry has the shading effects that is capable to barrier climatic problem that disturb crop growth. Agroforestry tree shading effect can buffer temperature and atmospheric saturation by decreasing contact excess temperature where developmental, physiological processes and yield increase vulnerable with low accumulation of organic matter resulting in poor soil structure with low infiltration rate and rise of runoff and erosion.

Climate patterns were analyzed using meteorological station data from 1983-2017 of monthly total maximum temperature, where the is occurrence of low stability of temperature variation during period of study. This shows low impact of the agroforestry tree species to the study area due to the age of the trees planted.

4.12. Evaluation of the perceptions of local people towards sustainable monitoring of the restored ecosystems.

Evaluating the perception of local people who lived before and after restoration towards sustainable monitoring of the restored ecosystems is somehow difficult. The results indicate 5.08% need trees with low crop competition as *Bambusa vulgaris* was also some of the trees used during restoration, 24.29% wish also to receive addition trees as some was not well grown, other died because of the diseases, 2.82% wish to benefits from the trees planted, 26.55 % wish if irrigation is promoted in the area would be as the compensation to the one having low agriculture production due to the lost land used during restoration,16.38% wish to have home gardens practice as the way of compensation,7.34% the request for follow up for their local leaders on the trees planted, 4.52% the need training on ecosystem services and management, 12.99% wish that they would have security on the Golden Monkey which is harming their crop and affect their agriculture production.

As some may know the role of restoring the area other may not, or some may know the role of using agroforestry others may not. Survey respondents who were asked about the measures that they can suggest protecting the ecosystem complex of Akanyaru Murago and Cyohoha, some were able to provide ideas other and this is related to the compensation that local communities wish to receive after restoration activities which they think will encourage them to sustain monitoring of the activities of the restoration.

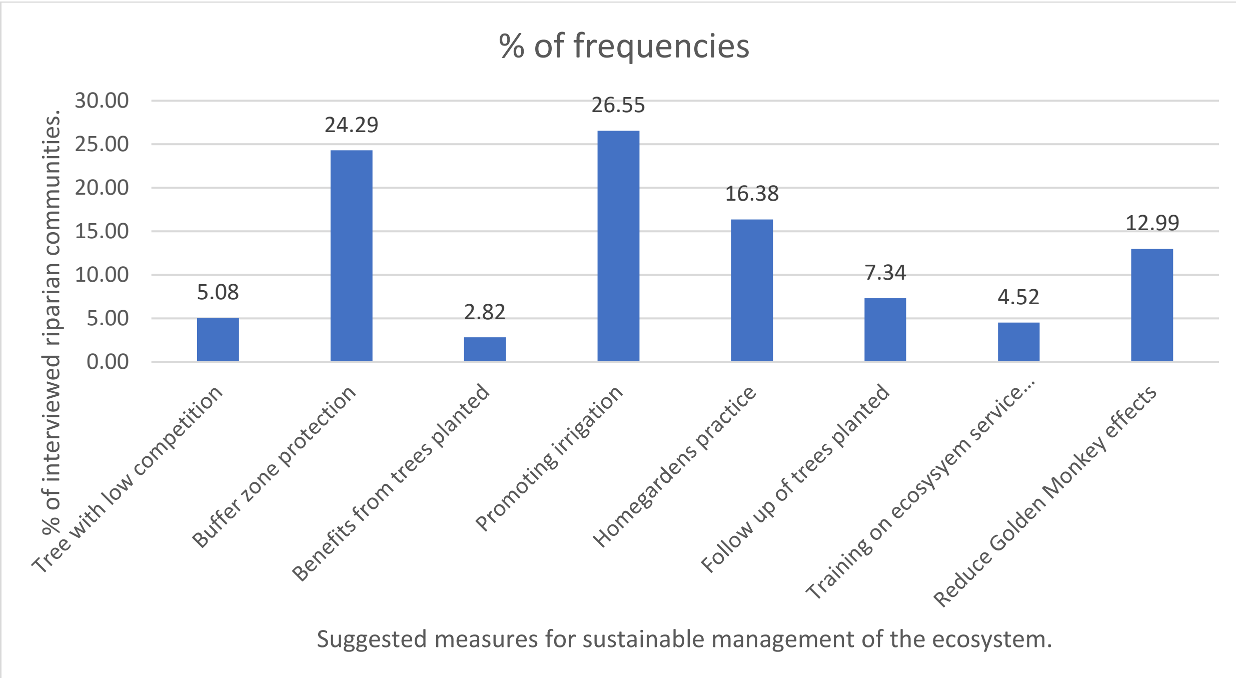

Figure 13: Suggested measures by riparian communities for sustainable management of the ecosystem

Chapter 5. Discussion

5.1. Demographic characteristics

In many context researches has demonstrate less access of female than men to resources production and opportunities to the technology, land, education, and extension(Kiptot, Franzel, & Degrande, 2014). Spreads of education has been proved in all areas to provide social, political, and economic development with its tentacles in all areas of life. where this arise the knowledge, improvement of skills and changing of attitudes and behaviors towards the implementation of the activity(Julius et al., 2012). And this is in line with (Oino & Mugure, 2013) who reported that respondents with low level of education is affecting high quality of the agroforestry system that do not necessitate much skills and knowledge and affecting the use of information. Interpretation and understanding of the households head is affected by the education level and the decision making.

5.2. Occupation of riparian communities

Agroforestry is known to contribute to the improvement of livelihood around the world, but the local people are still using local knowledge. Farming systems depend upon the nature and the irrigation resources and as such most depend upon agriculture, their interventions by introducing and taking care of an agroforestry practices and system used will ensure better economy of the restored area through agroforestry system, this can change their life style Agroforestry involves all these vibrant components and proficient of handling circumstances in better way. Using agroforestry food insecurity will is willed to reduce and removing pressure by conserving the soil and environment. The significant opportunity from agroforestry system for the livelihoods improvement through nutritional and economic security of people has been stated(Lorenz et al., 2018).

5.3. Benefits that local peoples gain from the restored ecosystems compared to the time before the restoration.

All over the world wetlands are considered as a very important aspect of the environmental resource which they produce a range of ecological and socio-economic benefits in their natural state which contribute to the well-being of rural communities and the environmental security of them. Different range of benefits has been mentioned to be provided from the wetlands as it contributes to the well-being of many people. All households nearby the wetland, in some rural areas will get water and reeds, however, not all households will benefits equally from wetlands(Wood, 2018). Any agroforestry system and practice are believed to provide a number of ecosystem services and environmental benefits that are useful to the livelihood development and to the climate change effects. Restoration wetlands using agroforestry leads to more esthetical environment, regulating the climate. Similar results emphasized by(Roshetko et al., 2002) smallholders farmers involving agroforestry trees species in their farm donate various benefits including environmental protection, water availability, food for human and livestocks, stakes, good air, ornamental materials. (Cerda et al., 2014)Agroforestry is able to provide various products to the people surrounding the ecosystem by improving the wellbeing.

5.4. Agroforestry systems, practices and species used to restore Akanyaru, Murago and Cyohoha ecosystems.

Restoration has increased it necessity due to the increase in climate change where go in hand with resilience, and its impacts is taken into consideration during project planning. The activities always aim those areas that are appropriate to climate change and inspire the use of species that will be use of species that will be stronger under new climatic conditions with the good adaptability to climate variability via choosing of the resilient species that will depend upon its genetic variation(Mansourian, Vallauri, & Dudley, 2005).

According to Nair (1993) in (Pancel & Köhl, 2016), Agroforestry practice as the distinctive arrangement of components in space and time while agroforestry system is defined based on as specific local example of a practice. A system is categories by the site-specific assortment of plant species, their management, arrangement, and socioeconomic concert. A specific arrangement of components, self-governing of the exact choice of locally adapted species. Agroforestry comes with many positive effects that benefit farmers and local communities, on and off-farm biodiversity, and soil health. Trees have a wonderful ability of remediating polluted soils and regenerating degraded lands.

In some areas, the presence of trees is encouraged as a vital part of land reclamation strategy and act as a conservation buffer as serving as protective barriers and this leads to the reasons why agroforestry trees used has powerful of mitigating the impact of farming activities on the surrounding environment by covering the banks of rivers, lakes and the wetland. This is because trees have irreplaceable role in preventing excessive nutrients from fertilizers, pesticide toxins and siltation from soil erosion from entering water and contaminating it. According to a study from 2014, a 60-meter-wide buffer zone of trees is capable of capturing up to 99.9 percent of nitrogen and phosphorus runoff from croplands

Agroforestry has been used widely in developing world as a strategy to manage effects of climate variability and bring resilience to the communities. Agroforestry combines agriculture and forestry technologies to create more integrated, diverse, productive, profitable, healthy, and sustainable land-use systems.

5.5. Source of information on wetland use and Management

Significance, importance, and the value of wetlands to a healthy ecosystem, biodiversity, clean, people's livelihoods and safe environment have been documented and recognized. In this regard a conceptual framework was provided by a Ramsar Convention Secretariat for a wise use of wetlands and maintenance of their ecological character (Ramsar Convention Secretariat, 2007b)in

(Kamukasa, Authority, View, & Adonia, 2018). This was addressed by various stakeholders to the riparian communities to the projection of sustainability.

5.6. Evaluate changes in levels of climate change effects before and after the restoration

Climate has the strongest influence on soil process that contribute to degradation, and this has the potential change to alter these processes due to changes in climate that affects soil conditions. There are several ways by which climate change displays soil degradation. Drought caused by high temperatures and drier conditions lead to poor organic matter accumulation in the soil resulting in poor structure, reduction in infiltration of rain water and increase in runoff and erosion (Rao et al.1998) in (Agroforestry, Chavan, Handa, & Newaj, 2017). Extreme rainfall has harmfully impacted on the severity, regularity, and extent of erosion due to flooding

5.6.1. Changes in Rainfall

Extreme rainfall events will harmfully influence the severity, frequency and extent of erosion while there is expected increase in its occurrence(Agroforestry et al., 2017)**.**Agroforestry system has been found to barrier the consequence of the dangerous weather in microclimate by decreasing the instabilities in both air and soil temperatures, humidity and responsible in decreasing wind velocity near the soil surface as, microclimatic variations in agroforestry systems also reduce soil moisture evaporation (Nasielski et al., 2015)

5.6.2. Changes in temperature

Agroforestry offers microclimate improvement as it has a major impact on crop performance in agriculture production, agroforestry has the shading effects that is capable to barrier climatic problem that disturb crop growth. Agroforestry tree shading effect can buffer temperature and atmospheric saturation by decreasing contact excess temperature where developmental, physiological processes and yield increase vulnerable with low accumulation of organic matter resulting in poor soil structure with low infiltration rate and rise of runoff and erosion (Agroforestry et al., 2017). (Zinov'ev & Sole, 2004) presented that an agroforestry system with a well-developed canopy can protect soil macrofauna from drought stress and temperature variation. Availability of low soil moisture has negative impacts on agriculture production due to the increase of evapotranspiration and temperature (Nguyen, Hoang, Öborn, & van Noordwijk, 2013).

5.6.3. Carbon measurement by loss on ignition

However In the West African Sahel region, little has been reported concerning C sequestration potential of agroforestry systems in semiarid and arid regions (Takimoto et al.., 2008). Agroforestry system combines numerous types of plant materials with the ability to hold and utilize natural growth resources such as water, light and nutrients. The system offers higher probability to sequester carbon than species with single crops cultivation, this is has become the source of carbon sink which deliver momentary storage of carbon (Handayani and Prawito, 2011) in (Mohd Salleh & Harun, 2013).Moreover the diversity and richness of plant materials species in agricultural land has a greater influence on soil organic carbon content present, this is produced by plant-soil systems that are possibly to mitigate the climate change (Somarriba et al., 2013)in (Mohd Salleh & Harun, 2013).

The net removal of CO2 from atmosphere by carbon sequestration and storage in long-lived pools of C, this involves soil microorganisms, below ground biomass such as roots, and aboveground plant biomass capable to relatively stable forms of organic and inorganic C in soil(Nair, Kumar, & Nair, 2009)**.**Determination of the baseline soil carbon stock is the major issue while evaluating and linking the C sequestration potentials of the land use systems. Some studies in Africa reported that planting trees for C sequestration will not directly hold soil C equal to the baseline level nor increase it in the short term(Takimoto et al., 2008)

Chapter 6. Conclusion and recommendations

5.1. Conclusion

There are many benefits arising from using agroforestry in restoring degraded wetlands for ecosystem restoration and mitigating climate change effects and bring resilience of riparian communities. Agroforestry is able to deal with problems and challenges of agriculture production and addressing the problem of droughts, floods which will have significant negative impacts on agriculture yields that may threatening the food security. All in all, the results of this study have shown that there are range of benefits and livelihood betterment arising from restoring ecosystem through agroforestry.

5.2. Recommendations.

Overcoming hurdles to the mainstream of Akanyaru, Murago and Cyohoha ecosystem complex to reach the resilience of riparian communities to climate change effects, in this thesis various challenges and barriers for the sustainable management of the wetlands were identified and solution were suggested.

Doing this will help to have beneficial effects on the restoration using Agroforestry system and practice on the success of the sustainability of the restoration and bring resilience to the riparian communities to climate change effects.

- ✓ More mobilization should be made to improve the understanding of the communities on restoration role.
- ✓ This research should be used as baseline for soil carbon stock present in the soil for further research.
- ✓ Further studies are recommended for physical chemical parameters.
- ✓ Negotiation between the government of Rwanda and communities should be made on how to benefits on the trees planted on buffer zone.
- ✓ Monkey coming to damage the crops should be managed.
- ✓ Local communities should have capacity building of planting and replacing the dead trees
- ✓ Compensation should be made to the riparian communities for those who cultivated near the wetlands for their loss of agriculture production
- ✓ Studies assessing the environmental impacts of Bambusa Vulgaris to avoid any negative consequences that may arise because of its potentially invasive character.

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APPENDICES

Appendix : Questionnaire

Questionnaire

Part A : Household's characteristics

Questionnaire for data collection

1. **Information of the respondent**

1) Name
2) Role in the family
3) Education level
4) Marital status
5) Sector
6) Cell
7) Village
8) Sex

9) Age
10) Time spent in the area (years)

2. Questions to be answered

1) What is your major daily occupation?
2) Have ever practice farming in the wetland?
3) If yes, what was/is your farm size?
4) Are you satisfied by the way the wetland is managed compared to before restoration?
5) Who informed you about changes in wetland use?
6) How did you react on changes in wetland use and management?
7) Have you participated in the restoration of wetland?
   a) If yes, what are the agroforestry trees did you plant, which practice and system used?
   b) If no, why didn't participate?
8) Are there any benefits you get from the restored ecosystem?
   a) If yes, what is the type of the income?
   b) Is the income enough compared to the one you gained before restoration?
   c) If you lost some income from the wetland, how did you compensate?
9) What are the environmental problems you faced before restoration practices?
10) Do you still face the same challenges?
   a) If yes, what are they?
   b) If no, can you predict the reason behind?
11) What have you been considering when restoring the ecosystem complex?
12) Do you know the role of planting Agroforestry trees?
13) Did the restoration of Akanyaru -Murago – Cyohoha ecosystem complex meet your problems on agriculture production or climate change mitigation?
14) Do you wish another method of agroforestry system?
15) Dou you know the role for protection of Akanyaru -Murago and Cyohoha ecosystem complex?
16) Do you practice farming to the riparian zone of Ecosystem complex of Akanyaru -Murago and Cyohoha ecosystem complex? Do you know that it is not allowed to practice any activity to riparian zone?
17) What are the measures that you can suggest to protect the ecosystem complex of Akanyaru Murago and Cyohoha?