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School of Architecture and Built Environment

MSc in Geo-Information Science for Environment and Sustainable Development

Effect of Ecosystem based Adaptation interventions on micro-climate variability and improvement of crop yields in Mushongi Cell, Mpanga Sector, KIREHE District, Rwanda

Thesis submitted to the University of Rwanda: College of Science and Technology in partial fulfillment of the requirements for the award of the Degree of Master of Science in Geo-Information Science for Environment and Sustainable Development.

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Declaration

I, Henriette KASHIRANDE declare that this is my original thesis entitled *"Effect of EbA interventions on micro-climate variability and improvement of crop yields in MUSHONGI Cell MPANGA Sector, Kirehe District, Rwanda".* It has not been presented at any other university.

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Approval

I certify that the present thesis entitled *"Effect of EbA interventions on micro-climate variability and improvement of crop yields in MPANGA Sector, KIREHE District, Rwanda"* was done by Henriette KASHIRANDE in fulfillment for the award of Master's degree in Geo-Information Science for Environmental and Sustainable Development, under my guidance and supervision.

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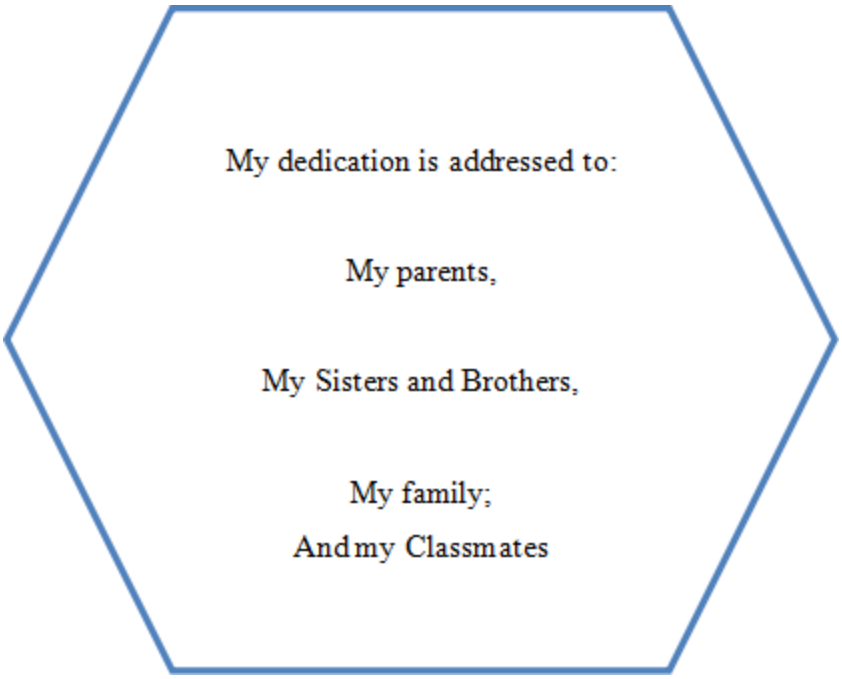
Dedicate


My dedication is addressed to:
My parents,
My Sisters and Brothers,
My family;
And my Classmates

Acknowledgement

The success of this work is not a chance; it is the result of my effort, supported by important persons and Almighty God for making it possible to finish this study. First and foremost, I thank Almighty God for his protection and abundant blessings during my studies.

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The lists of symbols and acronyms

REMA	Rwanda Environmental Management Authority
EbA	Ecosystem based Adaptation
SPSS	Statistical Package for Social Sciences
GIS	Geography Information System
GPS	Global Positioning System
USAID	United States Agency for International Development
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
UNEP	United Nations Environment Program
MINAGRI	Ministry of agriculture and animal resources
LCDF:	Least Developed Countries Fund
^0C	Degree Celsius
Mm	Millimeter
Kg	Kilogram

Abstract

The climate variability and change in Rwanda caused different issues like drought and floods as results of heavy precipitation and hot days. These issues affect negatively agricultural production leading to bad living condition. Ecosystem-based Adaptation (EbA) is a good solution to help human being to adapt to the unpleasant effects of climate variability and change. This Study on Effect of EbA interventions on climate variability and improvement of crop yields was conducted in Mushongi cell of Mpanga Sector, Kirehe District, Rwanda. It was conducted with three objectives. (i) To assess the impacts of EbA intervention on land use practices (forestry, agroforestry and crop land) (ii) To analyze the effects of EbA intervention on micro-climate variability (iii) To investigate the effect of EbA intervention on crop production.Both quantitative and qualitative methods were used to achieve the objective of research. A survey questionnaire with 220 respondents and 5 interviews were conducted. Remote sensing and GIS were also used to analyze land use change detection using satellite images and supervised classification techniques. The maps of land use were compared using GIS for land use change detection. SPSS software was used to analyze data from survey whereas NVIVO was used to analyze the data from interview. The results showed that the implementation of EbA project in the study area displayed a positive effect on climate variability mitigation and increase crop yield as well as land use change. About 92.3 % of respondents said that their land was used for agricultural (cropping) production whereas 100% of respondents highlighted that after implementation of EbA, their lands are used for agroforestry. EbA activities area played important role including fuelwood and stakes (97.7%) the the soil erosion control (96.8%); the planted trees in EbA protect plants against heavy wind (90.0%), generated income for farmers (88.6%), increased soil fertility through recycling of nutrient from the deeper soil with (85.5%). After EbA, crops were growing well as confirmed by 98.6% of respondents, rainfall was sufficient for 97.7% of respondents and coming on regular basis 91.4% of respondents). The yield of crops increased as confirmed by respondents. Around 87.7% of respondents said that the maize increased whereas 86.8% of respondents confirmed that the yield of beans was increased.This is study found that EbA approach improved adaptation of people to climate variability effects because farmers get different benefits both socio-economic and environmental. This study also recommends to use EbA approach to help people to mitigate the impacts of climate variability but also to investigate different factor that help crops to grow well in agroforestry system.

Key words: EbA, Ecosystem based adaptation, crops yield, Climate change

1. INTRODUCTION

1.1. Background of Study

There is considerable evidence showing that Earth has warmed up since the middle of the 19th century. The global average temperature has increased by 0.8^0c from the 1850s (Collier et al., 2008; Wheeler & Von Braun, 2013). Moreover, the global mean temperature for this century could be warmer by $1.8^0$to 4.0^0c than the end of century before. This global warming is linked with the increase of greenhouse gases emission into atmosphere (Wheeler & Von Braun, 2013) resulting in climate change (Collier et al., 2008; Wheeler & Von Braun, 2013).

Climate change is a global problem caused by emission of greenhouse gases into atmosphere (De Stefano & Jacobson, 2018). The main cause of climate change is natural resulting from anthropogenic activities that are causing emission of greenhouse gases including methane, carbon dioxide and other gases (Collier et al., 2008; Wheeler & Von Braun, 2013), the change of land use and the burning of different fuels. In 1832 the level of greenhouse gases in atmosphere increased from 284 ppm up to 397ppm in 2013 from human activities including burning fuels and changing land use (Wheeler & Von Braun, 2013).

The climate of Africa is likely to be affected seriously compared to other continents or region. The effects of climate change are not at the same level in the whole Africa, its level differ based on region. For instance, Eastern African region is expected to be wetter, while large part of southern Africa predicted to be drier and hotter. Briefly, some areas of Africa will become drier, others wetter, and some regions may derive economic benefit, while most are adversely affected. As warming increase all over the world, the temperatures are increasing on Africa continent and in the surrounding oceans. The level of warming is faster for Africa compared to the global average and this is more likely to remain(Collier et al., 2008) .

In the case of Rwanda, the annual mean temperature is around 20°C with annual rainfall of 1,250mm, but the observed data of the mean temperature of Rwanda has risen in recent decades to the higher level compared to that of global level. This means that the climate of Rwanda has

been changing and it is projected that temperature will increase from 1 to 2.5°C in the middle of this century (MINAGRI, 2018). So, the climate change of Rwanda can intensify several catastrophic events which include drought and floods (Mikova, 2015) due to the rise of heavy precipitation and hot days (MINAGRI, 2018). Climatic factors including precipitation, temperature, carbon dioxide and sunlight are the main key factors which influence growth of crops (Mikova, 2015). In Rwanda, the performance of agriculture was affected by climate change (MINAGRI, 2018) as a results of climate variability for a long period. That is why mitigation of climate variability affect positively climate change effects (Rind, 2012, 2017). Although, both climate change and variability are the highest problem nowadays, healthy ecosystems are capable to provide services and different benefits that support people's resilience to the effects of climate change. The main components of having a healthy ecosystem include natural sustainable management, restoration and conservation of ecosystem so that it can continue to supply or support human being to adapt climate change or climate variability (UNEP, 2019). On the other hand, when ecosystem is healthy, it can provide different life co-benefits, from cleaned water to drink, good habitat for living things, fertile and arable soils to other natural products that support economic growth, food security and human well-being (USAID, 2019).

People whose lives depend on ecosystems and biodiversity are highly sensitive to climate variability. Especially, people who lives in the rural areas must adapt to their living condition to the variability of seasons, drought, rainfall, and factors linked to climate (GIZ, 2020). Solving the problem of climate change is very important for protection of the world's poor and susceptible population and also decrease the risks to economic growth and increase of global security (USAID, 2019).

In line with adaptation to climate change and climate variability, Ecosystem-based Adaptation (EbA) is a nature-based method that combine both biodiversity and ecosystem services to aid human being to adapt to the unpleasant effects of climate change (USAID, 2019). Moreover, in amelioration of climate resilience, intervention of Ecosystem based Adaptation can provide different benefits including both environmental and socio-economic. Those benefits include conservation of biodiversity, protection of human beings and helping them to get what they need while mitigating climate change through carbon sequestration and improvement of agricultural productivity (USAID, 2019). So ecosystem based adaptation brings resilience and decrease

vulnerability to both risks (climate and non-climate) when delivering several benefits to community and environment (colls, 2009). When we protected ecosystem it can contribute to Ecosystem Based Adaptation (GIZ, 2020).

Different scientists (e.g. (Vignola et al., 2015; Aliyu et al., 2016) reported that agricultural practices such as agroforestry systems meet criteria of Ecosystem based Adaptation with the ability to protect food or cash crops, from challenges like storms. EbA provides water needed by plant through integrating agroforestry species trees and shrubs into crops and the farms of livestock (USAID, 2019). Vignola et al., (2015) said that applying conservation agriculture as a practice that meet criteria of EbA can rise climate resilience through minimization of disturbances to the soil's structure, composition and natural biodiversity. The wild species in agroforestry system deliver different alternatives when crops fail to produce due to ability of wild life to resist local conditions compared to commercial species (USAID, 2019).

Moreover, agroforestry systems have the ability to improve the capacity of ecosystem to withstand to climate variability and extreme conditions like heavy rain or droughts (Aliyu et al., 2016). it also is one of potential sustainable way for achieving a healthy soil in order to increase agricultural production and performance of environment (Sollen-Norrlin et al., 2020).

1.2. Problem statement

There are three greatest challenges for world in coming decades, those include climate change and variability, loss of biodiversity and water shortage. Loss of biodiversity leads to the loss of ecosystem services, climate change lead to water shortage and then rise risk of crop failure, pest infestation, livestock deaths and permanent land degradation while water shortage affects crop productivity, food security and human health (World Bank, 2009).

In Rwanda, variability and change of climate include the rise of average temperature and unpredictable rainfall. The latter affect negatively heath of landscapes and people's livelihoods. Drought and insufficient rainfall are some of the main results of climate variability in the eastern part of Rwanda. The occurrence and intensity of this problem are projected to rise and continue in the future in the Eastern of Rwanda as an effect of climate change (REMA, 2019).

Even though, Rwanda get different services from its several ecosystems including wetlands, savannahs and forests, local people are struggling to adapt to the impacts of climate change through remarkable contribution of ecosystem such as protection against the effects of climate change, absorbing wave energy and stabilizing shorelines from erosion. Ecosystems not only participate in mitigation of prolonged drought and floods but also deliver different services and products to the local people. On the other hand, agricultural and water sectors of Rwanda are mainly affected by climate change. Some effects among others are: (i) reduction of crop yield due to inadequate water and soil moisture, soil erosion (ii) reduction of crop yield due to crop damage as results of land sliding and flooding and (iii) reduction of quantity and quality of water due to drought and flooding (REMA, 2019).

Although EbA play an important role in adaptation of local community to climate change, they are at risk of deterioration and degradation due to unsustainable utilization of natural resources by people. So, to decrease the degradation of those ecosystems (wetland, savannah and forests) and help people to adapt to the effects of climate change, REMA recommends the application of ecosystem based adaptation (EbA) approach as one of the main solutions (REMA, 2019). EBA combine the use of ecosystem services and biodiversity into an overall approach to aid people to adapt to negative effects of climate change. EBA approach contains conservation/protection, sustainable management, restoration of ecosystems to deliver several services to help people to adapt to both current climate variability and climate change (Colls, 2009).

Ecosystem-based Adaptation decreases susceptibility to both non climate and climate risks and deliver different benefits including those related socio-economic, culture and environment(Colls , 2009). Moreover, EbA approaches contribute to the increase of management and protection of natural ecosystem, management of agricultural crops and natural resources in sustainable ways (World Bank, 2009). Through EbA, REMA has been implementing the restoration of degraded savannah and forests in KIREHE districts through the planting of 250 ha with agroforestry species; 68 ha with indigenous species and 20 ha with fruit trees and the restoration of 50 Ha of Rwampanga Lakeshores in KIREHE districts (REMA, 2019a).

Applying woody plant (trees and shrubs) based system is one way of overcoming the different challenges as it mitigates climate change and variability (Aliyu et al., 2016); maintain soil health (Sollen-Norrlin et al., 2020) and increase soil fertility, protect soil against erosion (Mulyono et al.,

2019). The mitigation of climate change is achieved through carbon sequestration by agroforestry system and forestry (De Stefano & Jacobson, 2018; Pantera et al., 2021; Rakotovao et al., 2022). So, suitable practices for land management are needed to reduce the degradation of soil and keep good quality of soil, increase soil productivity while minimizing poor soils (Mulyono et al., 2019).

On one hand, REMA implemented EbA approach to restore degraded ecosystems for helping people and other organisms to continue gaining benefits from ecosystems. On the other hand, it is very complicated to restore degraded land/ ecosystem while farmers are using resources from that ecosystem. So, decision-makers and landowners alike could understand and take steps to restore degraded land and prevent further degradation (Chasek, 2022). As Kirehe district known as a district facing a prolonged drought, leading to food shortage while there are other understandable limitation including lack and poor understanding of farmers on climate variability and their choice to grow crops without considering data from Meteo-Rwanda (Huggins, 2017). From the time REMA start the implementation EbA, there was no investigation on the effect that the EbA project is bringing in line with climate change adaptation. So, this study is conducted in line with the implementation of EbA approach to assess its impacts on ecosystem restoration in order to maintain good function of ecosystem. As healthy ecosystem mitigates climate variability and increase soil and crop productivity, this study is mainly focusing on the impacts of EbA approach on climate variability and improvement of crop yields in MUSHONGI cell, MPANGA sector of KIREHE District.

1.3. Objectives of the research

The research will be guided by the following general and specific objectives.

1.3.1. The general objective

The general objective of the research is to assess the effect of EbA interventions on mitigation of micro-climate variability and improvement of crop yields in MUSHONGI cell, Mpanga Sector, KIREHE district, Rwanda.

1.3.2. Specific objectives

The Specific objective will be:

1. To assess the impacts of EbA intervention on land use practices (forestry, agroforestry and crop land)
2. To analyze the effects of EbA intervention on micro-climate variability
3. To investigate the effect of EbA intervention on crop production.

1.4. Research questions

The research will be guided by the following research questions:

1. What are the impacts of EbA intervention activities on land use practices?
2. What are the effects of EbA intervention on micro-climate variability?
3. What is the effect of EbA intervention on crop production?

1.5. Hypotheses of the research

The research will test the following hypotheses:

1. EbA intervention has a positive impact on land use practices

2. EbA program contributes positively to the micro-climate variability mitigation

3. The implementation of EbA activities increased crop yields in the study area.

1.6. Motivation of Study

Climate change and variability linked with pollution and poor exploitation and human encroachment are rising, changing, deteriorating and degrading ecosystems and their capability to provide different services which affect living condition of human population. If ecosystems are well conserved and managed can increase the resilience of human being to climatic and non-climatic threat while delivering several benefits and services to both community and the environment. In light of this connection, there is growing recognition that ecosystem-based approaches to climate adaptation can constitute an important element of a country's strategy for adapting to climate change and variability (Tine Rossing, 2015).

This research will be helpful in different ways, firstly in knowing different effects of EbA intervention on improvement of crop yield and mitigation of climate variability. Secondly the finding of this research will empower the existing knowledge about the importance of Ecosystem based adaptation approach, this will be encouraging farmers to adopt this approach so that they will maintain a healthy ecosystem. After maintaining the healthy ecosystem, the livelihood of local community will be improved.

2. LITERATURE REVIEW

2.1. Climate change and climate variability

The climate of earth is dynamic, meaning that it has been changing for a billion years. The climate variability come before climate change. Climate variability is defined as changes in climate on the timeline of seasons to decades (Rind, 2012). For instance: climate variability reflects how one season was cold while another was hot and how one decade was drier than the other. On the other hand, climate change reflects long term changes from decades to longer (century) and permanent variations in global or local climate trends. For instances climate change could highlight changes that occurred in 30 years or more (Rind, 2017).

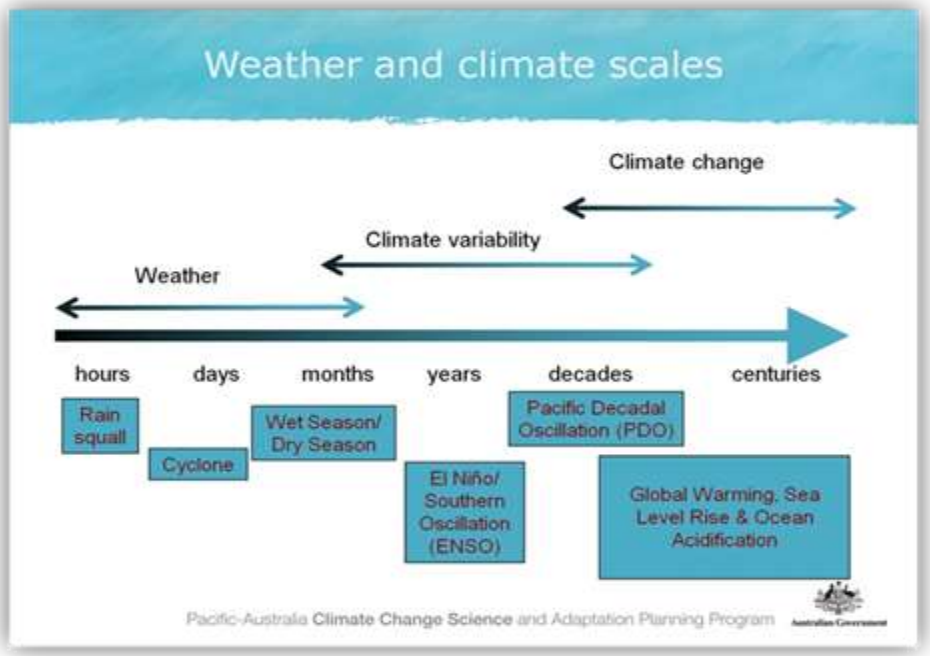


Figure 1 ***A guide to the timescales applicable to weather, climate variability and climate change.***

Source: https://www.pacificclimatefutures.net/en/help/climate-projections/understanding-climate-variability-and-change/-2007

On the one hand, figure 1 illustrated that weather is characterizee by variation of hotness and coldness in the very short time such as hours, day up to months. Climate variability is change of hotness and coldness in short period from months, years to decades of years. On the other hand, climate change is charazeizee by variation of this hotness and coldness in many decades of years to centuries of years.

Climate change is a long-term change of temperatures and weather patterns. This change may occur naturally due to changes in the sun's activity (temperature) or large volcanic eruptions. On the other hand, from 1800s), anthropogenic activities have been the major driver of climate change, mainly as a result of burning of fossil fuels like coal, oil and gas (https://www.un.org/en/climatechange/what-is-climate-change. Cutting down forests and clearing of land are activities that are causing emission of carbon dioxide into atmosphere whereas oil, gas and agricultural operations are the main cause of methane emission (Thomas Fakana, 2020). These activities produce greenhouse gases emission and then those gases make something like blanket that cover Earth, trapping sunlight and then increase temperature. Methane and carbon dioxide are the major greenhouse gases that are leading to climate

change (https://www.un.org/en/climatechange/what-is-climate-change). Climate change is caused by emission of greenhouse gases into atmosphere. Emission of carbon dioxide from anthropogenic activities to atmosphere resulting in the rise of carbon dioxide concentration in atmosphere (De Stefano & Jacobson, 2018);

2.2. Ecosystem functions

Ecosystems is an interaction of all living organism and non-living things with each other in their place or area of living or environment where they live. As an example, biotic factors such as animals and plants interact with ecological conditions or environmental conditions (abiotic factors) like sun, rainfall, soil, weather, atmosphere that support those biotic factors to grow. In every ecosystem, both biotic and abiotic factors usually rely on each other, so the lack of one may affect or disturb all other factors in that ecosystem (UNEP, 2019).

When ecosystem is healthy, it provides wide range of benefits to support life, Some among them are cleaned water for drinking, habitat for plant and animals, soil fertility for plant growth, food security and human well – being (USAID, 2019), decrease of soil erosion (Swiderska et al., 2018). Ecosystem services are classified as regulating, provisioning, cultural and supporting services (Swiderska et al., 2018; UNEP, 2019). Degradation of ecosystem challenge its ability to generate these services (UNEP, 2019).

Ecosystems functions can be interrupted by human or natural activities. Anthropogenic activities affect ecosystems negatively including pressure, linkage to population increase, transport, energy and agricultural requirements. On the other hand, natural factors which affect ecosystems contain fires, floods, volcanic eruption and climate change. These activities result in environmental degradation due to pollution, overexploitation and mismanagement of different ecosystems. This degradation may lead to the pollution of soil, water and air, introduction of invasive species, loss or fragmentation of habitat and deforestation. When ecosystem is polluted, it may destabilize the availability of well cleaned water which affect negatively human health, livelihoods and societies (Malhi et al., 2020). The changes of ecosystem status make local community or people more susceptible to natural problem like climate change. When some regions become warm as result of climate change, this may cause migration or extinction of animals or plants species. There is expectation of continuity of climate change in the future

due to change of land use, density and increase of population and human behavior, this will cause different effects on ecosystem function (UNEP, 2019).

2.3. Climate change and Ecosystem function

Nowadays there is a relative effects of climate change on biodiversity and ecosystem compared to direct human activities like conversion of land use, over exploitation that results in the loss of habitat for other species. The negative environmental effects of climate change are becoming more outward and more likely to be intensive over future decades. Climate change is increasing its effects on land, those effects are: increase of rainfall variability, increase of exciting dryness and wetness, long term warming and rising water deficient into atmosphere are rising physical and hydrological stress and ecosystem flammability (Malhi et al., 2020).

Climate change and Global warming have been causing negative effects on ecosystem and species living in that ecosystem. Wetlands, mangroves, coral reefs, cloud forests, and Arctic ecosystems are more susceptible and it is expected that climate change will continue to increase probability to extinct species in those ecosystems. Climate change can affect the distribution, species reproduction, species behavior, and species migrations, as well as occurrence of pests and diseases and all of which are likely to affect crop production, food security, and human health (World Bank, 2009).

UNEP (2021) highlighted the negative effects of climate change on ecosystems, some among them are risk of drought, floods, rising temperature, reduction of rainfall, water shortage soil erosion, landslides and desertification all affect degrading ecosystems and reduce their capacity to deliver services to the community, reduce rain feed agriculture and livestock as well as causing harm to people (UNEP, 2021). Keeping up ecological connectivity and decrease of additional degradation of ecosystem and habitat will be critical approaches for protecting and conserving biodiversity and ecosystem services (World Bank, 2009).

2.4. Ecosystem Based Adaptation

EbA is an approach based on nature where ecosystem services and biodiversity are used or integrated to help local communities to withstand different effects of climate change (colls , 2009); GIZ, 2020; Swiderska et al., 2018; UNEP, 2019, 2021; USAID, 2019). Ecosystem based adaptation is a people-centric concept that knows ecosystem integrity as critical for human resilience to climate change (USAID, 2019).

Ecosystem based adaptation approach include different activities like protection, sustainable management and restoration of ecosystem to provide both products and services of an ecosystem that help local community to withstand variability and change of climate (colls , 2009); Swiderska et al., 2018; USAID, 2019) EbA approaches contribute to the decrease susceptibility and rising the capacity to recover from both climate and non-climate risks and then after deliver different goods and services to the environment and people (colls , 2009).

2.5. Principles of EbA

Swiderska et al., 2018, highlighted principles for any approach or activity to be qualified as EbA, it might address all of the follow three elements (i) Help local community to adapt to effects of climate change; (ii) Active utilization of biodiversity and ecosystem services, (iii) In the context of an overall adaptation approach (Swiderska et al., 2018)

These above three elements may be broken down into five key criteria, which can be used to ensure EbA measures are effective, EbA should: (i) decrease both social and ecological (environmental) susceptibility to climate change, (ii) provide social benefits and support the most vulnerable (iii) maintain, restore, or improve ecosystems and biodiversity (iv) be mainstreamed into policies at multiple levels (v) Support equitable governance and enhance capacities (Swiderska et al., 2018)

2.6. Why integration of EbA

Regardless on the efforts put on mitigation of climate change, already climate change is happening and projected to become more serious and we are not in the way to achieve our mitigation goal. So, climate change adaptation is immediately needed. Beside the mitigation efforts, most countries have

responsibility to adapt to the present and projected impacts of climate change (Malhi et al., 2020; Swiderska et al., 2018; UNEP, 2021). The most susceptible countries are immediately looking for the best approaches to adapt climate change that is why they spread new technology and capacity building. So, EbA as approach integrate the uses of both ecosystem services and biodiversity as adaptation method to help local community to adapt different impacts of climate change. This approach has aims of maintaining and rising resilience and decrease susceptibility of ecosystems and local community facing several impacts of climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies.(UNEP, 2021).

Briefly EbA contributes to the conservation of ecosystem and biodiversity and climate change adaptation to provide both social and economic benefit (Swiderska et al., 2018). EbA have guidelines which define why addressing the problem of climate change risks via EbA provides the achievement of very wide development goals. So by putting local community (people) in the center, EbA integrates community based and fully participatory methods to the local level and then go up to the high level like provincial or national. This is for guiding the activity of planning and policy development to increase adaptation effects (UNEP, 2021).

2.7. Intervention of EbA in Rwanda

In Rwanda, Ecosystem and biodiversity living in ecosystem deliver services necessary for helping people to adapt to the effects of climate change. Nowadays EbA has increased a cost-effective solution to adapt to climate change and disaster risk management. EbA approach highlights the significance of ecosystems in effective climate change adaptation measures, and builds on other practices such as conservation and ecosystem restoration that seek to increase the resilience of ecosystems and communities. Rwanda, through REMA, has developed and adopted different strategic plan to transform the economy in mid-21st century. These plans emphasize on acceleration of development with sustainable management of natural resources and climate resilient surroundings (REMA, 2019c)

2.8. EbA intervention to adaptation to climate variability and change

Planting plants are competent method to EbA, plants are very important in change of environment condition or circumstances including reduction of negative impacts caused by climate change. Plants reduce long term increase of temperature for neighbors. Plants have ability to reduce the effects of temperature, on the other hand, predetermined choices to plant trees or to increase tree covers to alleviate the increase of temperature are part of EbA. Management that rise plant cover reduce desertification effects (Espeland & Kettenring, 2018).

Establishing tree based ecosystem is efficient approach of EbA, trees based ecosystem play an important role because they are helpful in biodiversity conservation, soil erosion control, enhance water quality. Trees play a vital role in carbon sequestration resulting in mitigation of climate change. It is also well known that litter fall from trees based ecosystem increase organic matter into the soil resulting in the increase of water retention capacity and water infiltration. These are one of activities which reduce flooding in the period of heavy rainfall (Khaniya et al., 2021).

2.9. EbA activities and agroforestry

As implemented in Rwanda, the EbA method has been applied to restore degraded ecosystems including forests, wetlands, and savanna. In this restoration different EbA activities were applied. Those include: establishment of agroforestry system, planting fruit trees, bamboo planting, and indigenous tree species planting, providing cows, and building rainwater harvesting tanks, among other activities (Nsengimana et al., 2021).

EbA covers a wide range of actions including agroforestry, crop rotation, grass hedge/stone bunds, in-field water drainage channel, and intercropping, to maintain and strengthen ecosystem services that underpin agricultural productivity and resilient food production. The main EbA approaches that contribute to agricultural productivity is agroforestry systems (Abravi Essenam Kissi, 2023; Soulama et al., 2020) .Agroforestry practices are multipurpose settings that have ability to provide several benefits including socio-economic, cultural and environmental. It has also ability to ameliorate soil fertility (Umuhoza et al., 2023). Agroforestry is considered as practice that promising farmer's livelihood improvement and positive environmental effects. It is also climate smart agricultural practice that increase food security and help to achieve objectives of adaption and mitigation to climate change (Simelton et al., 2017).

Agroforestry is the technology of overcoming the agricultural challenges as it mitigates climate change (Aliyu et al., 2016), and it maintain soil health (Sollen-Norrlin et al., 2020). Firstly, mitigation of climate change is achieved through carbon sequestration by agroforestry system. The sustainable atmospheric carbon sequestration into the soil is achieved through agroforestry system which provides a kind of potential confidence on atmospheric carbon sequestration into the soil (De Stefano & Jacobson, 2018; Pantera et al., 2021; Rakotovao et al., 2022). Thus, Soil has ability to store around 1.5 to 3 times of amount of carbon sequestrated more than vegetation. Generally, soil has ability to store around 60% of carbon stored in agroforestry or other tree based systems (De Stefano & Jacobson, 2018). So, maintenance of forest or agroforestry cover plays an important role on climate change mitigation. Moreover, around 25% of total greenhouse gases produced worldwide come from destroyed forests alone. On the other hand, forests all over the world have ability to store more than double amount of CO_2 that found in the atmosphere into the soil and trees' biomass (Bennett, 2017).

Secondary agroforestry has a considerable potential as a major alternative land use management for maintaining and conserving soil health and fertility. Woody plants and other vegetation located in agroforestry system have ability to improve soil properties underneath them (Nair, 1993; Young, 1989). Agroforestry and forest covers increase the soil fertility through litter fall decomposition, protect soil against erosion and mitigate climate change. So, suitable practices for land management are needed to fight degradation of soil and keep good quality of soil, increase soil productivity while conserving critical soil quality (Mulyono et al., 2019).

EbA approach for increasing biodiversity is designed as a bio-infrastructure that rise the supply of services from ecosystem and deliver several long-term benefits to the people, more specifically through accessing the natural resources and livelihood opportunities. Local people, who have access to forestry and agroforestry resources and whose livelihood depend on forest exploitation. Tree based system provide food, timber and non-timber forest product to the farmers while providing environmental services (Sajad Ghanbari et al., 2021). Forest and agroforestry or other tree based ecosystem are among EbA approaches that provides several benefits including products and services. Those benefits include: (1) Supply of goods for local community, (2) regulation of microclimate, water flow, soil for more resilient production, (3) Protection of soil against effects of climate change, protection of coastal areas against threats (4) tree based system in urban areas

regulate temperature and water for resilient urban area. There is several evidence showing that that EbA applied with forests and trees based system can reduce social vulnerability to climate hazards (Pramova et al., 2012).

2.10. EbA and the increase of crop productivity

EbA approach as Nature-based solutions to climate change and variability have different benefits: some among them are: biodiversity conservation, carbon sequestration, water security, land restoration, erosion control, and food security. This nature based solution, provide benefits to smallholder farmers, through conservation and rising of ecosystem services such as soil organic matter, water resources and several species of biodiversity (Shah et al., 2019).

The above conservation can result in rising crop productivity and increase production stability while decreasing the cost. To apply sustainable land management, ameliorate soil properties such as fertility and structure, this practice also conserves soil and water and increasing mechanism of soil nutrient cycle and the biomass ofthe soil and diversity of soil fauna. All of these benefits leading to high yield and greater resilience to climate change, thus contributing to improve food security and rural livelihood (Shah et al., 2019).

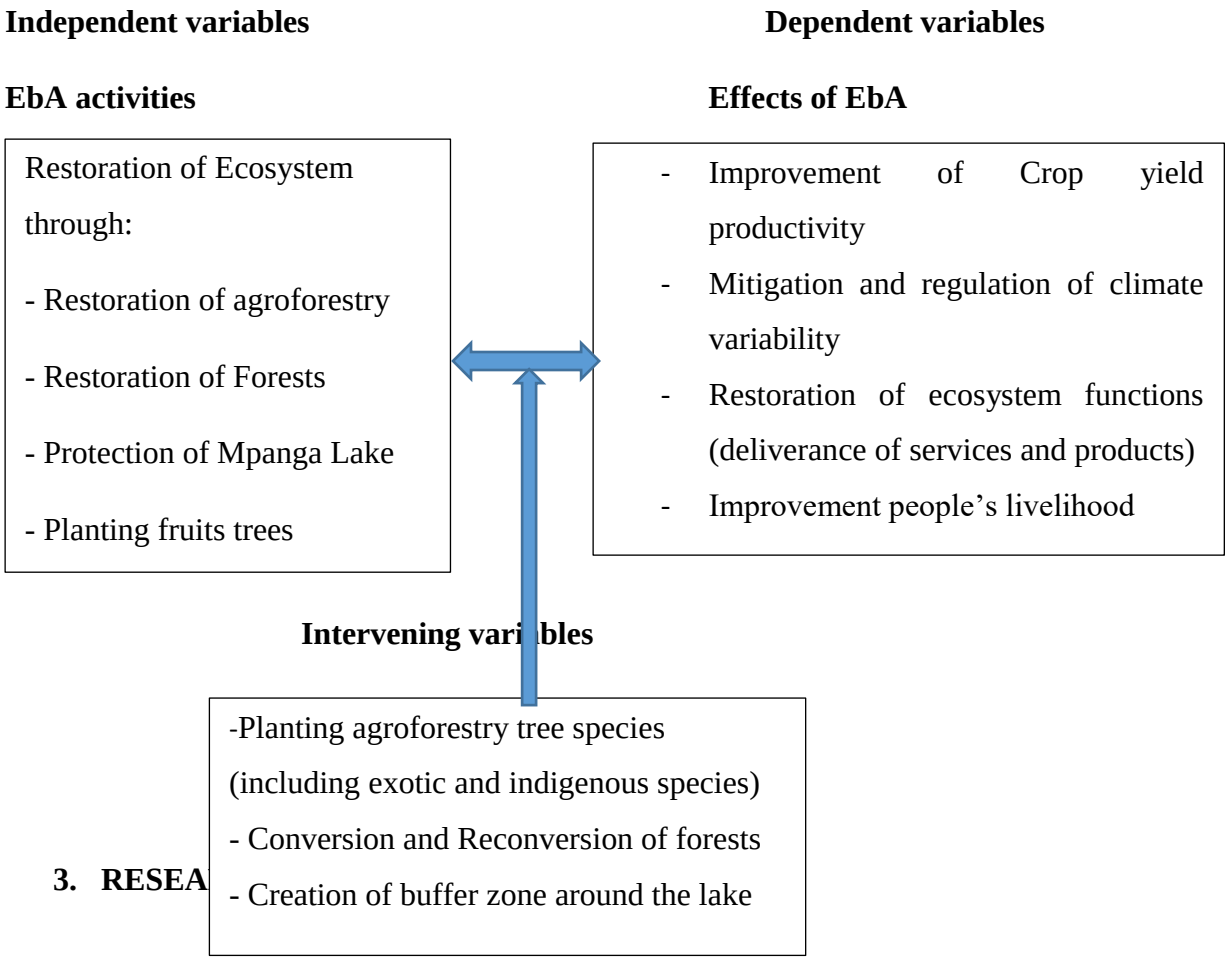
2.11. Research gap

Healthy ecosystems play an important role in deliverance of several services worldwide especially in Rwanda. Those services include resilience of local people to the climate change and variability. Even though ecosystem deliver several services, it is faced by different threats including drought, floods and land sliding due to high population pressure and improper use of natural resources. This is leading to degradation of ecosystems and then after reduce their capacity to deliver services which increase vulnerability of local population to the effects of climate change and variability. Restoration of ecosystem has shown that it doesn't help in addressing environmental degradation and climate change or climate variability only but also promotes deliverance of yields and products that sustain the livelihood of people. So, EbA approach creates significant socio-economic benefits to local people, through protecting them from climate variability or change and extreme weather events(REMA, 2019b).

On the one hand, REMA has developed guidelines to promote EbA and then gave training to the local people on development and methods of ecosystem restoration. On the other hand Colls, (2009) highlighted that EbA is the best natural response to climate change. In relation with the implementation of EbA by LDCFII, Umuhoza et al., (2023) conducted a research with objectives of (i) identifying agroforestry species planted in area where EbA was being appled, ii) evaluating agroforestry technologies adopted by local farmers: iii) examining the contribution of agroforestry to the supply of tree products to the smallholder farmers, and iv) identifying the challenges affecting adoption of agroforestry technologies.

1.13. **Conceptual framework**

The conceptual framework interlinks independent variables including EbA activities such restoration of agroforestry, plantation of indigenous and exotic species and restoration and protection of **Mpanga** lake and **Ibanda-Makera** whereas dependent variables include improvement of crop yield and mitigation of climate variability.



3. RESEA

3.1. Introduction

This chapter presents the description of the study area, methods and techniques, tools that will be used in data collection, and data analysis in order to obtain and analyze the information necessary to answer research objectives. The methods used in this study include literature review, questionnaire survey, interviews and field observation.

3.2. Presentation of the study area

Kirehe District is one of seven districts of Eastern Province of Rwanda. This district is composed by twelve sectors including Nyarubuye, Nyamugari, Nasho, Mushikiri, Musaza, Mpanga, Mahama, Kirehe, Kigina, Kigarama, Gatore and Gahara. Kirehe districts has 60 cells and 612 villages. This District shares boarders with Tanzania (districts of Ngara and Karagwe) in the East, Burundi in South, Ngoma district in the South Western part and District of Kayonza in the North (KIREHE, 2019) It is located in the savanna region of the country. in the two last decades, Kirehe District has been subjected to intensive deforestation resulting in degradation of forests and savannas due to search for fuelwoods as source of energy. As consequence, This might have contributed to environmental challenges including climate change (REMA, 2023).

The climate of this area is characterized by annual mean temperature ranging from 20^0c to 21^0c whereas precipitation is ranging from 700mm to 950mm. It is also characterized by two dry seasons and two rain season, (UMUHOZA , 2021). This study will be conducted in Mushongi cell of Mpanga sector, Kirehe district where 250ha were restored using agroforestry, in cell that is located in lakeshores of Rwampanga where bamboo and agroforestry species were planted on 50 Ha (REMA, 2019a).

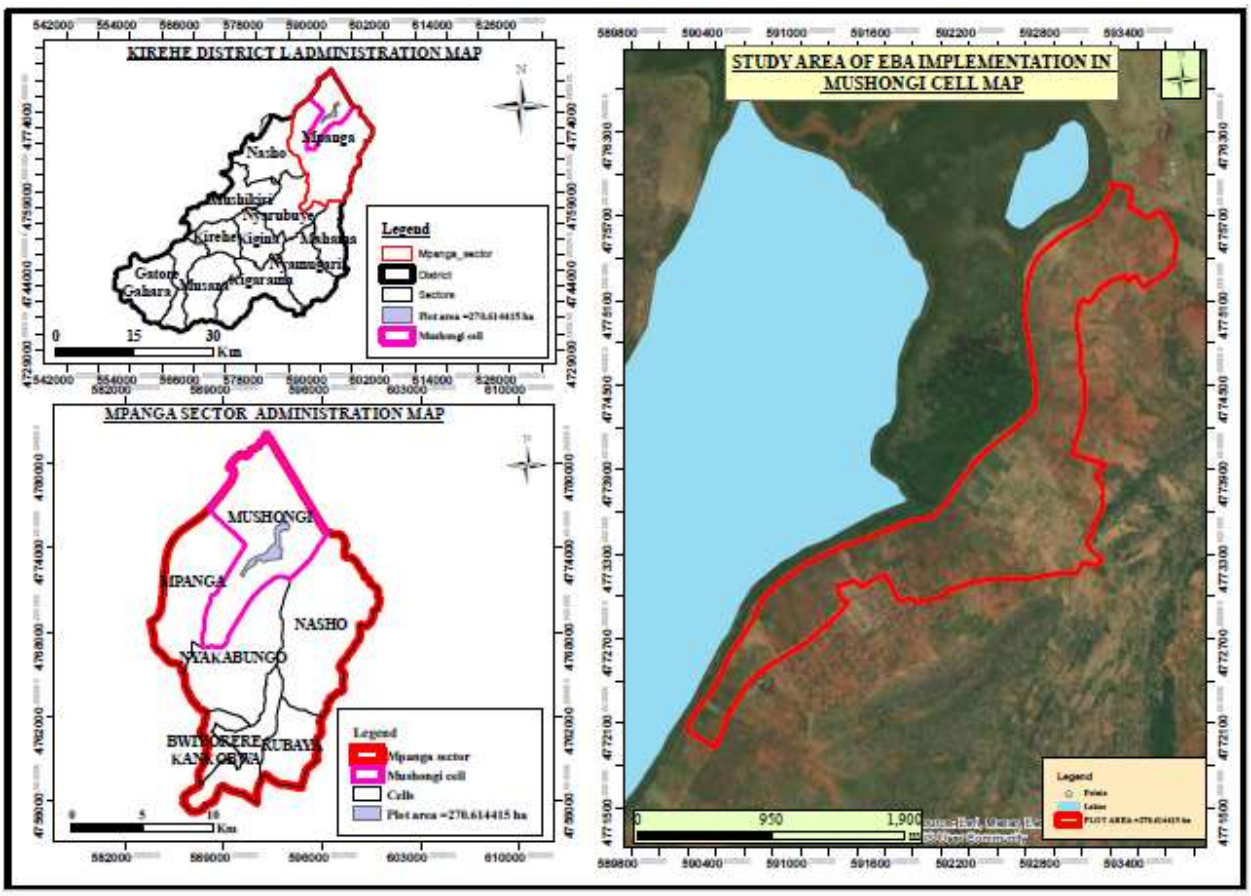


Figure 2 Map of study area (Own produced with ArcMap and field data 2024)

3.3. Research design

This study used both qualitative and quantitative data in order to achieve set objectives. Using both qualitative and quantitative data were helpful due to the complementarity between them. Quantitative data was gathered by measuring and counting whereas Qualitative data delivered deep explanations on the aspects of interest in the study that is why the findings from qualitative data validated findings from quantitative data and vice versa. The qualitative data were collected using interviews from leaders (5 interviewees) who have a certain level of understanding and knowledge about EbA. The quantitative data were collected using a questionnaire survey (data from 220 respondents). In this effort, the respondents were selected regardless of the level of education. In both survey and interview, the researcher selected respondents taking into consideration the requirements for each mode of enquiry.

3.4. Data collection instruments

After preparing questionnaire and interview guide, I used them when visiting selected respondents in order to collect needed data.

3.4.1. Questionnaire

The questionnaire survey also incorporated different questions including some related to the crop yield obtained before and after implementation of EbA.

The questionnaire survey was distributed to the sampled people taken from 489 households who benefited directly from EbA activities in the study area. Those people included households that have a restored land by agroforestry on lakeshores of Rwampanga lake.

3.4.1.1. Determination of sample size

$$n = \frac{N}{1 + N(e)2} \; ; \; n = \frac{489}{1 + 489(0.05)2} = 220.02 \approx 220 \text{ respondents}$$

Where, **n** is number of households sampled, **N** is the total households having farms where EbA activities are carried out, **e** is the precision level considered 5%. A 95% confidence level was taken and e= 0.05,

3.4.1.2. Sampling techniques

The sampling technique used was random sampling within the study area where EbA activities were carried out. After I reached the study area I worked with Socio-economic development officer who supported me with the provision of the list of households who benefited from EbA program and then we selected 220 households from them and the after I did interview with the staff in charge of socioeconomic development of studied cell, agronomist of studied sector, district forest officer District agronomist of district and district environmentalist.

3.4.1.3. Primary data

Primary data for this study were collected from survey where we visited different households and ask them questions related to the study. After arriving to the field, we collected data to be used in mapping the study area.

3.4.2. **Interview guide**

The interview guides targeted people who have a certain level of understanding on the EbA program including socio-economic economic development officers, sector agronomist, sector forest officer and district agronomist and environmentalist.

3.5. Secondary data

Different documents were read and satellite images were downloaded. In line with secondary data, remote sensing and GIS were used to analyze land use change detection using satellite images and supervised classification techniques. So, to investigate the changes of land use, we used supervised classification techniques. In this research, the satellite images of study area before and after implementation of EbA were downloaded, classified, using supervised classification. A classified image or change detection map needs to be compared against reference data, assumed to be true, to assess its performance and quantify its accuracy. The process was followed to estimate the accuracy of image classification by comparing the classified map with a reference map (Tewabe & Fentahun, 2020). And then I compared the difference and change of land use.

3.6. Data analysis

SPSS software was used to analyze data from survey after data collection and recording those data while data from interview was analyzed using NVIVO. Survey data analysis was descriptive in nature. Remote sensing and GIS were used to analyze changes of land use. After discussion the conclusion was taken and recommendation was set.

4. Results and Discussion

4.1. Demographics of the respondents

The respondents were grouped into classes based on their sex where the females stand at 40.9% whereas the males represented 59.1%. The respondents are distributed into age categories based on their ages where age category of younger ones is between 18 and 25 while the age category of older is >66. After getting the information on age category of young respondents I arranged age group by respecting an interval of 10 years. The mode age class is 36-45 with percentage of 39.1% This mean that the average age is in the range of this class. Based on marital status of respondents, around 95.0% of respondents were married, 3.2% of respondents were single whereas only 1.8% of them were widow and widowers.

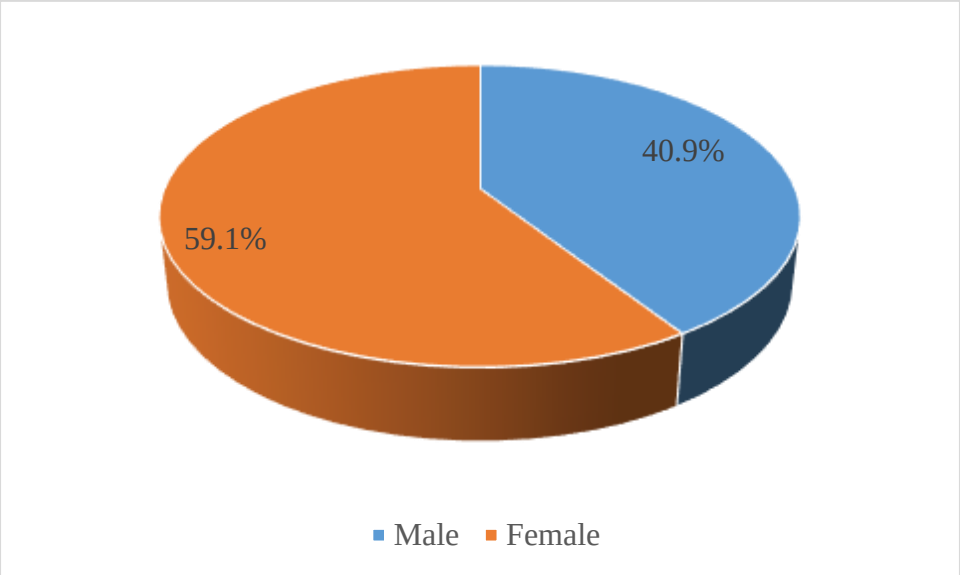


Figure 3: Distribution of Sex of Respondents

Age Class	Frequency	Percent	Cumulative Percent
18-25	3	1.4	1.4
26-35	21	9.5	10.9
36-45	86	39.1	50.0
46-55	54	24.5	74.5

55-65	39	17.7	92.3
>66	17	7.7	100.0
Total	220	100.0	

Table 1: ***Distribution of respondents according to age class (field data, 2024)***

The education level of respondents is diversified. The majority of them (82.3%) attended primary school followed by respondents who attended secondary school (14.1%) whereas 1.8 % attended TVET schools. Only a few respondents attended informal and university (0.9%) for each.

4.2. Plots ownership

About 91.4% of respondents confirmed that they own their plots for more than 10 years, about 8.2 % of respondents owned the plots for a period between 6-10 years whereas only 0.5% owned the plots for a period between 3-5 years. Pearson product correlation of age of respondents and plot ownership found to be moderately positive and statistically significant at 0.01 level with r=.503 with p-value .000.

4.3. Changes of land use

During data collection, most respondents (92.3%) said that before implementing EbA, their lands were used for agricultural production, meaning that the land use was agriculture without any trees planted in their lands. On the other hand, only 7.7 % of respondents said that before the implementation of EbA, their land was used for agroforestry production. All respondents (100%) highlighted that after the implementation of EbA, their land is used for agroforestry production, contrary to the use of land before EbA introduction. In implementing the EbA approach, the project played a big role in land use change, where it contributed to the development of agroforestry as confirmed by 89.5% of respondents. The project also contributed to the distribution of tree species of fruits for 10.5% of respondents. Around 100% of interviewed people said that before the implementation of EbA, most farmers had very few trees on their farms, which means that land was used mostly for crop production (Agriculture) rather than agroforestry. Those interviewed highlighted that the EbA project was mostly involved in agroforestry establishment. So, as reported by interviewed people, in the implementation of all EbA in the study area, all farms were

used for agroforestry. This change of land use from cropping to agroforestry was done to help the local community get different benefits from the ecosystem, including firewood, stakes, to fertilize the soil, and protect crops from heavy sunlight. Due to the effects of EbA activities, the farmers in the study area are proud of the EbA approach, as other farmers around the study area need to have trees on their farms.

The results of this research are also confirmed by the finding from the report of REMA (2019), saying that an area of 250ha of an agroforestry system was established along the lakeshore of Lake Mpanga in Mushongi cell, Mpanga Sector, Kirehe District. Moreover, different species, including exotic agroforestry trees, fruit and indigenous trees, were introduced and then delivered to farmers in project sites with the objectives of restoring the degraded savannah ecosystem and protecting the wetland along the lakeshore to help people to withstand impacts of climate change (REMA, 2019).

The figure 3,4 illustrates the change of land use before and after the implementation of EbA. The satellite image taken in 2017 showed that the main land cover in the study area was vegetation, meaning small vegetation, which was not trees. It means the main land use was agriculture. On the other hand, the map of the study area of 2024 shows the change of land use that took place after seven years. The land use was changed where area occupied by mere vegetation was reduced. During our research we mapped the area highlighting tree cover in order to show the increased tree plantation through agroforestry systems, as promoted by REMA through the project.

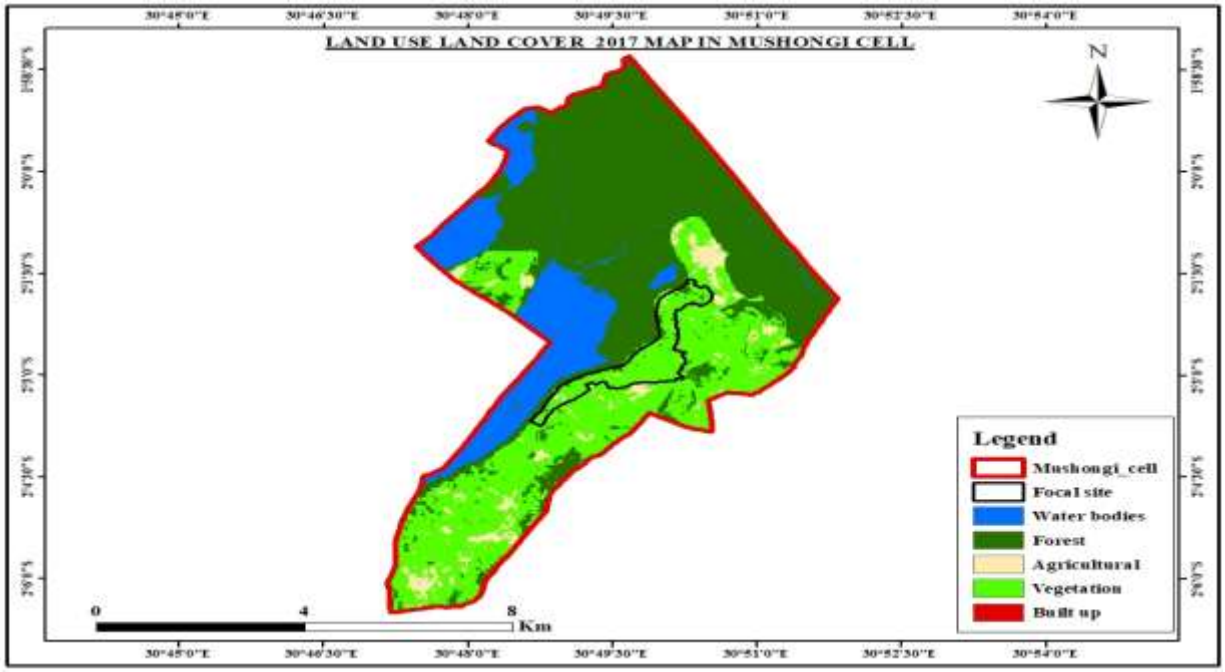


Figure 4. Land use, land cover 2017 Map in MUSHONGI Cell (own produced with ArcGIS) Source of data: United States Geological Survey (USGS) and field data 2024

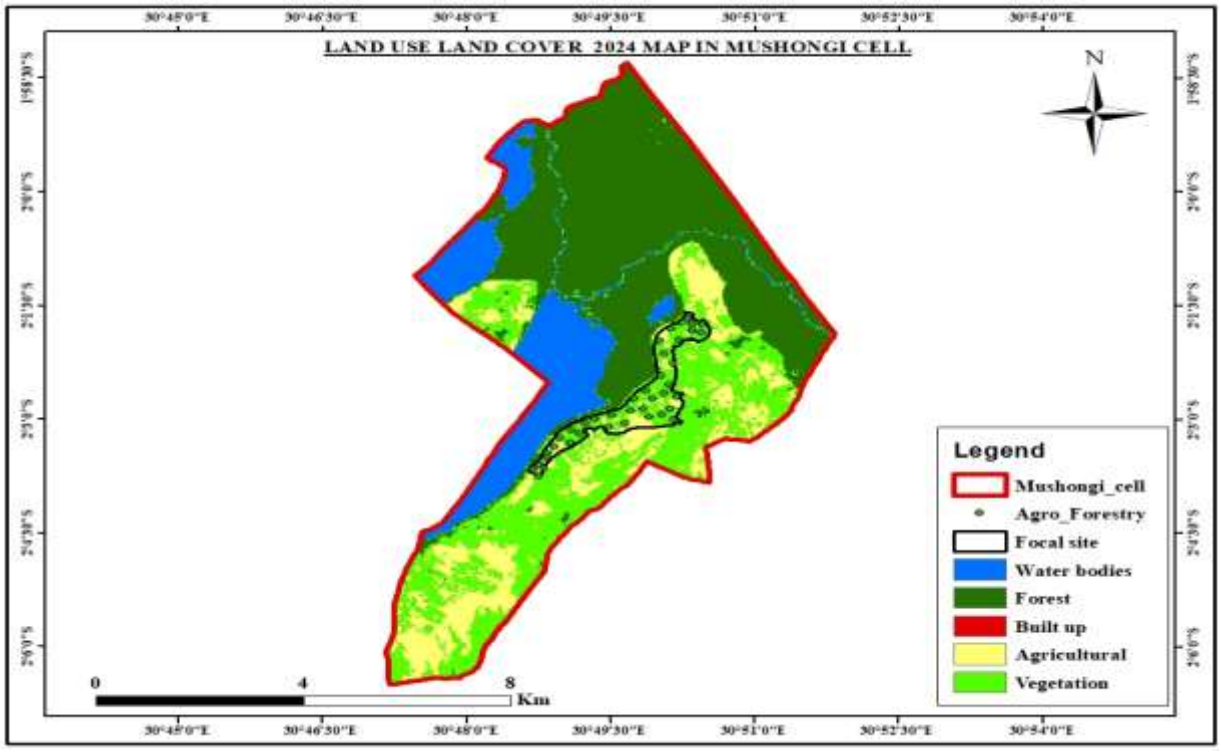


Figure 5 Land use, land cover 2024 Map in MUSHONGI Cell (own produced with ArcGIS) source of data: United States Geological Survey (USGS)

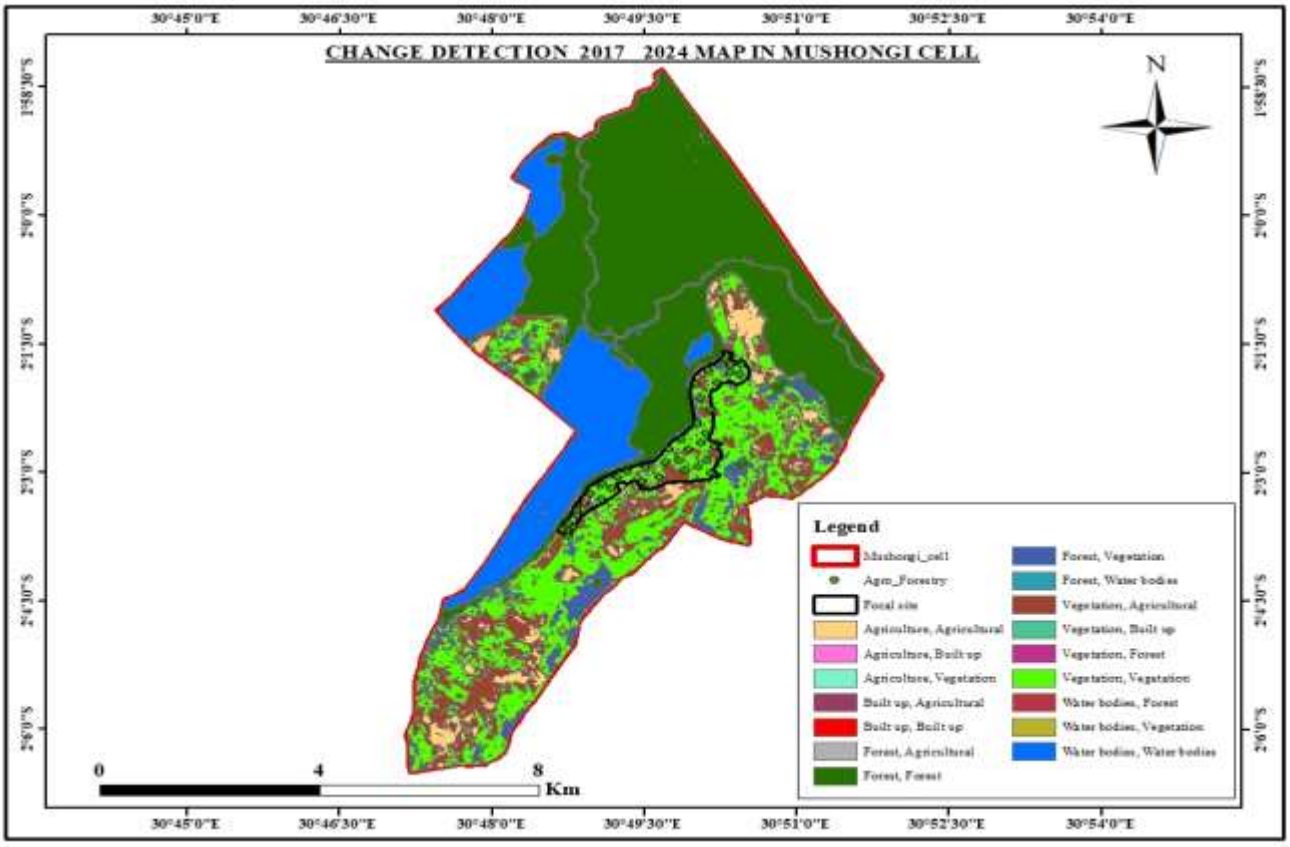


Figure 6 Change detection 2017 2024 mapping in Mushongi cell (own produced with ArcGIS)

Source of data: United States Geological Survey (USGS)

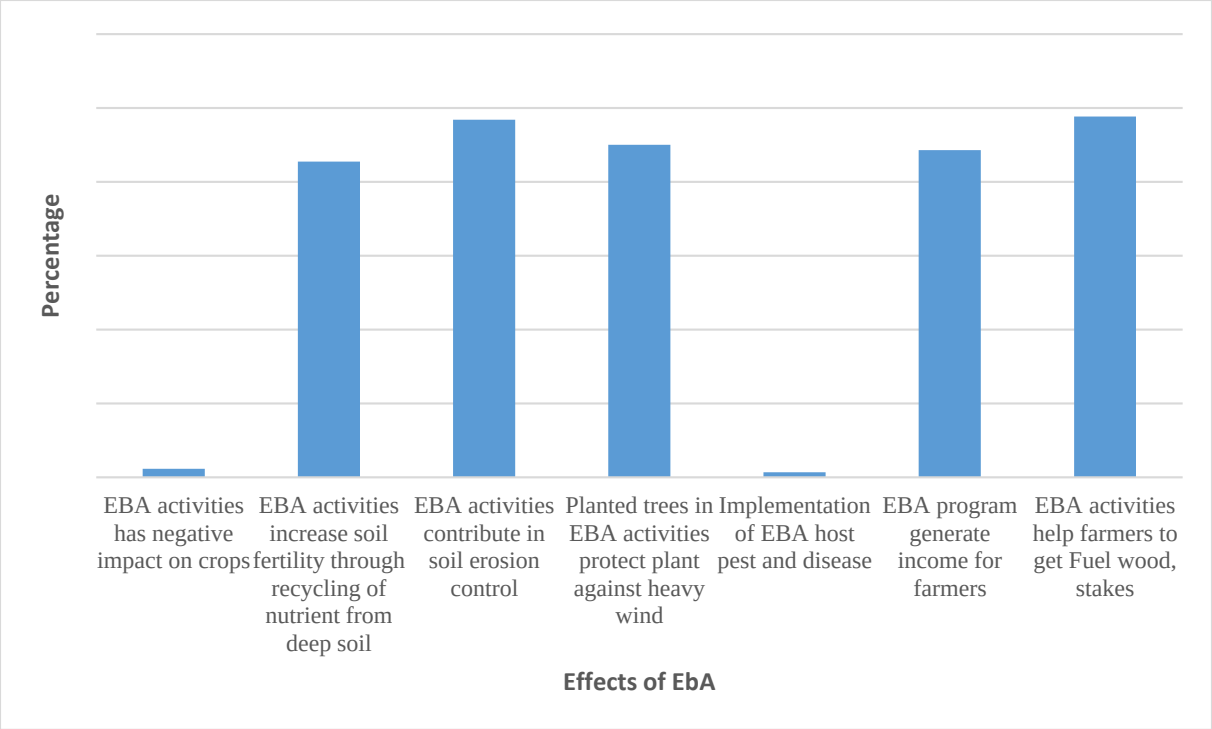


Figure 7. The effects of EbA intervention (field data 2024)

EbA activities in the study area played important role as the majority of respondents highlighted that EbA activities helped farmers to get fuel wood and stakes (97.7%) contributing to the soil erosion control (96.8%). The planted trees in EbA protect plants against heavy wind (90.0%), generated income for farmers (88.6%), increased soil fertility through recycling of nutrient from the deeper soil (85.5%). A few respondents said that EbA activities have negative impacts, like hosting pests and diseases, and negative effects on crops, with 1.4% and 2.3% respectively. The findings of this research present similarities with other research for instance, Shah et al. (2019) reported that the EbA project has positive effects on biodiversity conservation, water security, carbon sequestration, land restoration, erosion control, and food security through the amelioration of soil properties such as fertility and structure. EbA practice also contributes to soil and water conservation while increasing the mechanisms of the soil nutrient cycle and adding biomass to the soil and diversity of soil fauna (Shah et al., 2019). Those woody plants in agroforestry produce goods like stakes, firewood, poles, timbers, fodder for animals, fruits, and medicines.

4.4. Effects of EbA intervention on micro-climate variability

EbA activities play an important role in the mitigation of micro-climate variability. This was confirmed by 98.6% of respondents who said that the climate varied after the implementation of EbA. The effects of EbA on climate variability were identified in the form of temperature, which was reduced after intervention. After the introduction of EbA, crops were growing well as confirmed by 98.6% of respondents, rainfall was sufficient for 97.7% of respondents, and was coming regularly (91.4% of respondents), and there was no drought for 90.0% of respondents. The respondents said that before the implementation of EbA, the crops were faced with different environmental problems, including a long period of drought, resulting in a reduction of crop production as well as wilting of their plants. Respondents said that there was insufficient rainfall, but nowadays EbA contributes significantly to the mitigation of micro-climate variability and regulation of climate. The findings of the current study are similar to those of the study conducted by Donatti et al., 2020, who reported that EbA activities play an important role in the reduction of the effects of drought, the extreme weather events that cause loss of crops. It was reported that trees planted in the EbA program play a critical role in carbon sequestration, leading to the mitigation of climate variability and change (Khaniya et al., 2021). It is also well known that litter falling from tree-based ecosystems increases organic matter in the soil, increasing water retention capacity and water infiltration. These are part of activities which reduce flooding in the period of heavy rainfall (Khaniya et al., 2021).

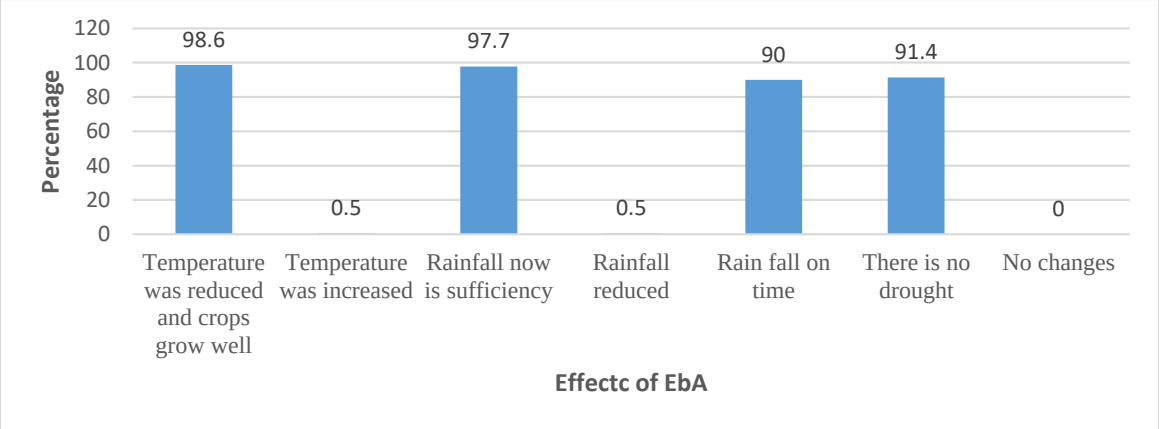


Figure 8 Impacts of EbA on Climate change parameters (own survey)

Source: Our field study

Respondents in our study area highlighted different environmental problems faced before implementation of EbA approach. Temperature was high and damaging crops due to drought (97.7% of respondents), there was no sufficient rainfall as estimated by 99.1% of respondents, there was low water retention capacity resulting in wilting of crops (91.4% of respondents) and no trees planted to capture rainfall (95.0% of respondents). The planted trees reduce temperature and increase organic matter into the soil resulting in the increase of water holding capacity as organic matter look like sponge which hold water. Our findings are in line with the study conducted previously that highlighted that the increase of trees' cover with the ability to reduce the effects of temperature and then the raising of plant cover reducing the desertification effects (Espeland & Kettenring, 2018). The tree planted in agricultural land increases local or regions rainfall; reduce temperature, and mitigate future drought (Baker, 2021).

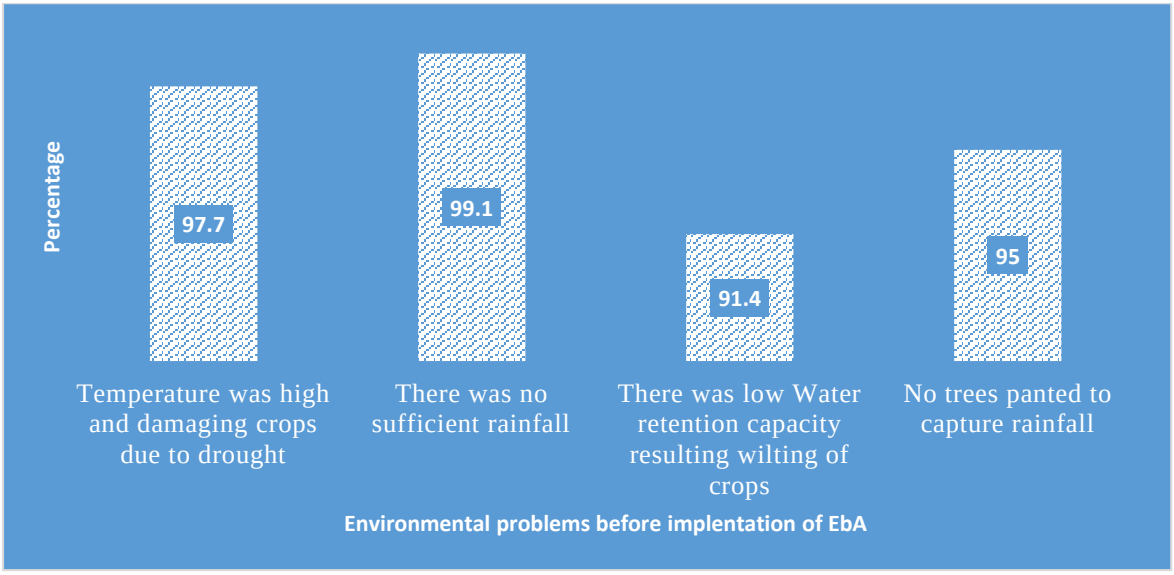


Figure 9 Environmental problems before implementation of EbA (field data 2024)

The respondent to interview said that after implementation of EbA, temperature was reduced and this reduction of temperature was due to the ability of trees (agroforestry species) to cool the envirenoment by capturing carbon from atmosphere through the process called carbon sequestration. Those people also said that rainfall was increased after intervention of EbA. Even through those interviewed people they said that they are very sure if the increase rainfall was due to EbA and estimated that rainfall increased as planted trees was growing. Even though large number of interviewed people highlighted the positive impact of EbA intervention on climate variability especially reduction and increase of rainfall some people said that they are not sure if

the planted agroforestry species impacted positively those climate factors. In this line, climate (temperature and rainfall) vary and can reduce or increase even if they do not affect large area because of small area restored while the change of climate takes very large area. So, it is difficult to know and quantify the effect of planted trees on climate. All interviewees said that in the study area (restored area) the temperature reduced due shade provision to crop compare to unrestored area. The precipitation in the study area are the same as other area expect the planted trees help in conservation of water leading to increase of soil holding capacity.

The findings of this study present similarities with data from meteo- Rwanda, where the data taken by Meteo-Rwanda from 2017 up 2023 showed that the rainfall increases whereas temperature were reduced in whole study area (Mpanga area). The figure 9 below showed that precipitation (rainfall) was increased. From 2017 to 2023; Although, rainfall intensity changed, it was increased as it is illustrated on figure 9. Even though the highest amount of rainfall was obtained in 2018, the following years do not reflect big differences.

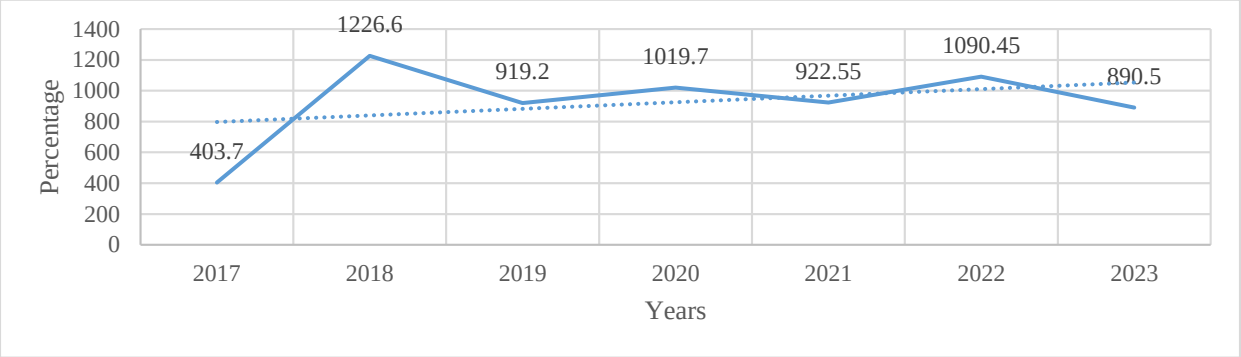


Figure 10: ***The precipitation in the study area (Meteo-Rwanda, 2024)***

Meteo-Rwanda recorded both minimum and maximum temperature reached every day. The results from recorded temperature by Meteo-Rwanda, from 2017 to 2023 showed that temperature was reduced in both maximum side (figure 10) and minimum side (figure 11) as follow: daily maximum temperature was 17.8^{0}C (2017), 24^{0}C (2018), 23.6^{0}C (2019), 24.9^{0}C (2020), 24.2^{0}C (2021), 22.3^{0}C (2022), 15.7^{0}C (2023) whereas daily minimum temperature were 12.7^{0}C (2017), 15.8^{0}C (2018), 15.1^{0}C (2019), 16.9^{0}C (2020), 16.4^{0}C (2021), 15.1^{0}C (2022), 10.9^{0}C (2023). It can be observed that temperatures varied as it is illustrated on figure 10 and 11.

Figure 10 and 11 showed the data from Meteo-Rwanda, showing that the extreme temperatures were reduced in both side (maximum and minimum temperature). These were considered in the

whole study area. This study focusing on the impacts of EbA intervention activities, the trees planted in Mpanga sector Mushongi cell contribute positively to the reduction of temperature while mitigating the progressive increase of temperature, even if the pace of reduction is low.

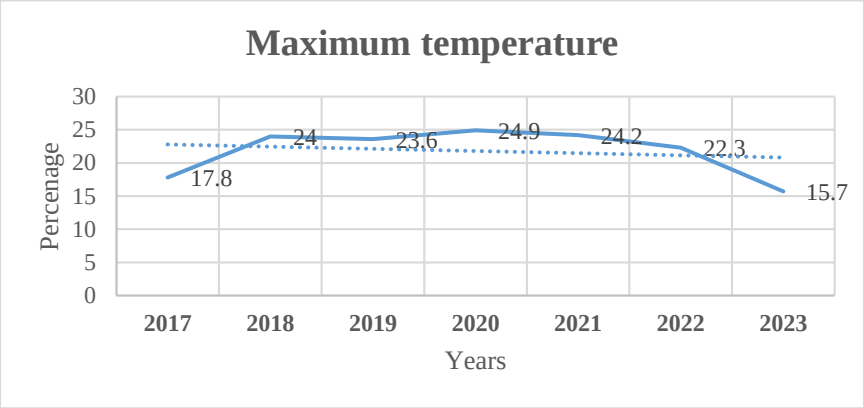


Figure 11: **Maximum daily temperature (Meteo-Rwanda, 2024)**

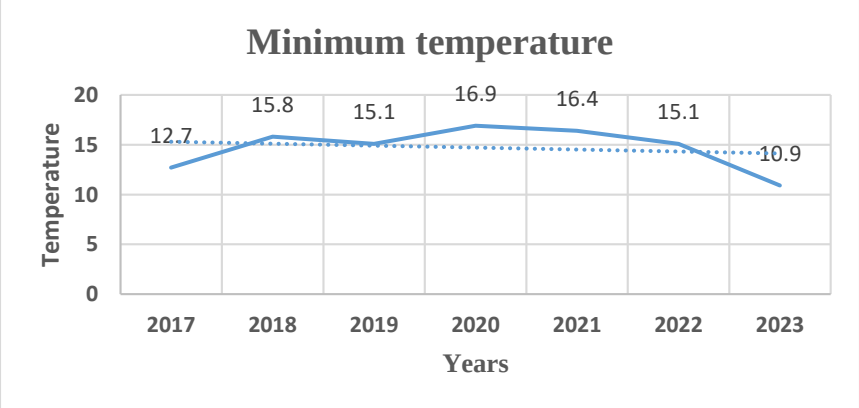


Figure 12: **Minimum daily temperature (Meteo-Rwanda, 2024)**

4.5. Environmental benefits from EbA activities

The findings of our study showed that the implementation of EbA had environmental benefits in the study area. EbA activities contribute to the mitigation of micro-climate variability as mentioned by 97.3% of respondents, purification of water and air (94.1 % of respondents): change microclimate for crops benefits (89.5% of respondents): provided shade to crops and animals and the habitat for biodiversity (49.5% of respondents). The respondents confirmed that after planting agroforestry species, good changes happened in the form of regularization of climate through the cooling of the the site and increase of rainfall. The planted trees also provided oxygen to farmers while changing micro climate and providing shade to crops, increase nutrients through decomposition of the litterfall from trees. Respondents also said that after planting trees the soil

organisms such as warms were increased. The current study is in line with another study that demonstrated that agroforestry applied through EbA approach has different environmental benefits. Viswanath et al., 2018 affirmed that agroforestry practices have the potential to increase and achieve sustainability of ecosystem. It has the ability to optimize the agricultural productivity, diversity, profitability and mitigate the impact of climate change. The findings from Ndayambaje & Mohren (2011) present similarities with our owns. They said that in agroforestry practice, woody plants are grown in combination with crops. They provide also different services like improvement of soil fertility and soil conservation (Ndayambaje & Mohren, 2011). Agroforestry provides environment benefits such as carbon sequestration, soil water quality conservation, biodiversity conservation, soil fertility and health improvement, and conservation of ecosystem (Jose, 2009; Nair, 2007)

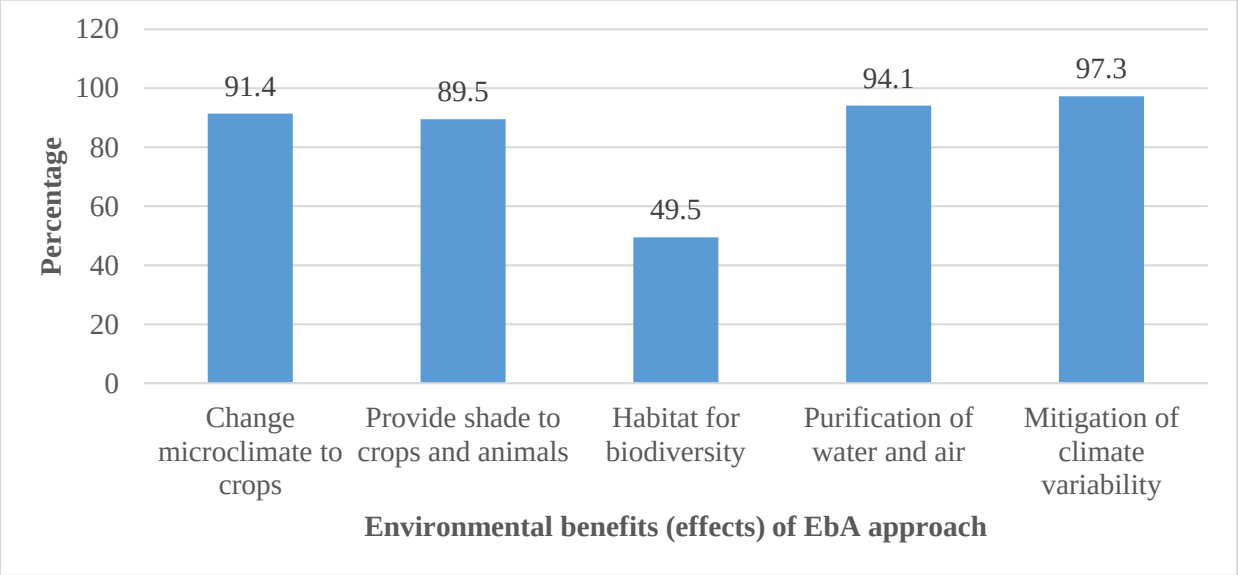


Figure 13: Environmental benefits from EbA (field data, 2024)

All respondents to interview reported that EbA intervention through agroforestry have positive impact on micro-climate where the planted trees increased biodiversity like worms and other soil microbes into the soil, protect soil against heavy sunlight by provision of shade and litter fall which involves in maintenance of soil moisture content. Those environment impacts affect positively crop production. Those people also said that agroforestry contribute in air purification through photosynthesis process resulting in climate regulation.

4.6. Major crop grown in the study area

The respondents highlighted different crops grown in the study area. The major crops highlighted include maize for 100% of respondents, beans stand (100% of respondents) and sorghum stand for 69.5% of respondents. Farmers rotate cereals crop like maize and sorghum with beans in the study area.

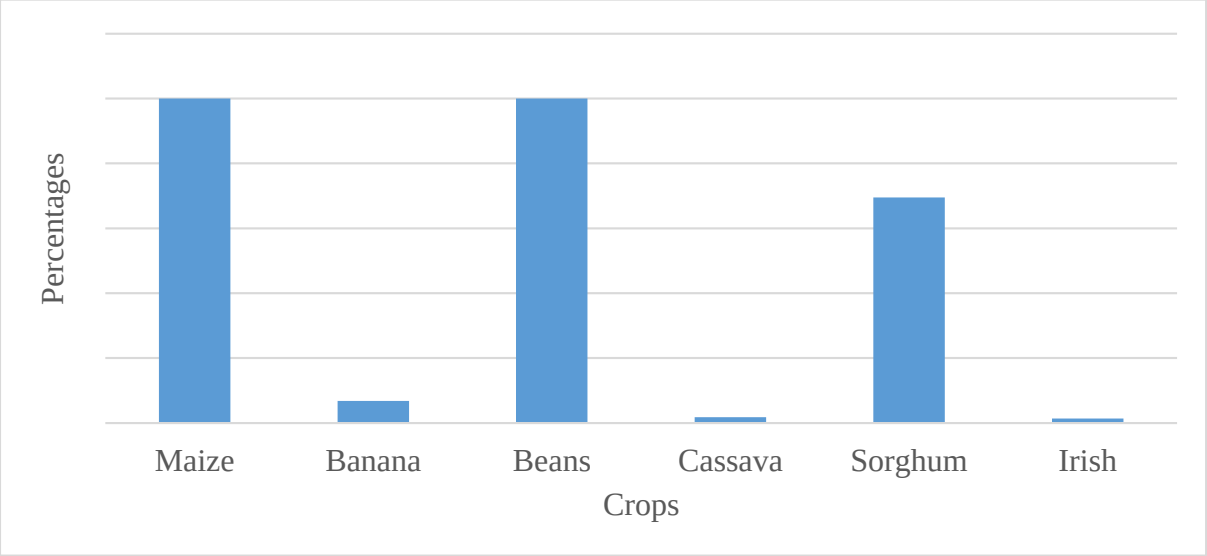


Figure 14 Most preferred crops in the study area (field data 2024)

4.7. Impacts of EbA activities on crop yields

During data collection we focused on two major crops grown in the study area which were maize, and beans. The results of this study showed that after implementation of EbA approach the crop yield increased. By considering two main crops mostly grown in the study area, 87.7% of the farmers said that their yield of maize increased whereas 10.0% of respondents said that yield of maize was reduced due to EbA activities, only 2.3% of respondents had the yield of maize reduced due to EbA activities. On the other hand, by focusing on the yield of beans, the majority of respondents (86.8%) confirmed that the yield increased as results of EbA intervention in the study area. A few respondents (representing 10.5%) said that the yield of beans was reduced. Only the respondent equivalent to 2.7% confirmed that the yield of beans didn't change. This means that

for the majority of respondents the yield of beans before and after implementation of EbA increased.

Crops	Yield increased after EbA intervention	Yield reduced after EbA intervention	No change (no increase or decrease)
Maize	87.7%	10.0%	2.3%
Beans	86.8%	10.5	2.7%

Table 2: Increase of Yield due EbA intervention

The average yield of maize obtained before intervention of EbA was 33.23kg per Are whereas yield obtained after was 40.30kg per Are. On the average, yield of beans obtained before implementation of EbA was 33.37kg per Are whereas yield obtained after were 36.02kg per Are.

The table 2 showed t-test of yield obtained before and after EbA intervention. The mean difference for maize was 7.068Kg per Are with 5.608 of standard deviation. The mean difference was highly significant at 0.01 level with p-value 0.000. The mean difference for beans was 2.645kg per Are with standard deviation of 4.124. This mean that the difference was highly significant at 0.01 level with p-value <0.01. Respondents said that the yield of their crops was increased due to intervention of EbA program that contribute to the change of microclimate for crops and gain in rainfall. The findings of current study have similarities with study conducted by Yoseph et al. (2023) highlighting that agroforestry provide different benefits like crop yield as well as improved soil health. Agroforestry contribute to modifying environmental conditions like nutrient availability, regulating temperature, ensuring water quality and soil conservation and thereby improving microclimate for crops grown.

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Dev.	Std. Er. Mean	Lower	Upper	T	df	Sig. (2-tailed)

Maize	After - Before	7.068	5.608	.378	6.323	7.813	18.694	219	.000
Beans	After - Before	2.645	4.124	.278	2.097	3.193	9.515	219	.000

Table 3: ***Difference in yield obtained before and after implementation of EBA (field study 2024)***

In the interview, interviewees said that the production of crops increased due to the EbA activities, which were used for different purposes. In the restored area, soil erosion was controlled as all respondents (100%), planted trees and fertilized the soil as trees help the soil retain much water planted trees help to protect crops against heavy sun, and planted trees to protect the soil against sunligh. All those points lead to an increase in yield. The yield increase varied based on the kind of crops and season, but generally, the yield increased from 2021, when planted trees were starting to have an impact on yield.

The interviewed people) reported that EbA activities significantly increased crop yield. EbA activities included planting trees, most are agroforestry species that fertilize the soil and conserve soil moisture content. After planting those trees, crops were grown with the trees and fertilized with different fertilizers. That is why farmers were proud of this approach of EbA adaptation as the key factor positively affecting increasing crop yield in the study area. Only 6.7% of respondents estimated that agroforestry can not increase crop production significantly because the planted species in the study area, as an EbA approach, compete with crop for light and nutrients. This means that only one person interviewed said that the agroforestry species used, which was Grevillea robusta is not good for crops.

On the other hand, all interviewees highlighted that the main challenge in the implementation of EbA was the poor participation of farmers in the implementation of planned activities, which negatively affected the success of this project. The project had to pay people who participated in planting trees. After planting trees, some farmers didn't manage the trees well due to due to poor collaboration.

4.8. Rejecting and Accepting Hypothesis

REMA in 2019, said that before the implementation of EbA in the study area, the main activities on this site were livestock keeping and agriculture. In the implementation of EbA, the area of 250ha of agroforestry system was put under cultivation along the lakeshore of lake Mpanga in Mushongi cell, Mpanga Sector, Kirehe District. Moreover, different species including exotic agroforestry trees, fruit tree and indigenous species were brought and delivered to the farmers in project sites with the objectives of restoring degraded savannah ecosystem and protecting the wetland along the lakeshore to help people to withstand the impacts of climate change (REMA, 2019). On the other hand, our findings indicate that land use was changed as confirmed by respondents. The majority of respondents (92.3%) said that before implementation of EbA, their lands were used for agricultural production without trees plantation. All respondents (100%) said that in the framework of implementation of EbA, their lands is used for agroforestry production contrary to the use of land before EbA. The land use change detection showed that land use was changed in seven years (from 2017 to 2024) as showed by satellite images taken and classified in order to check differences using change detection. So, with all above mentioned evidences the hypothesis that EbA intervention has impact on land use change (practices) can be validated.

The findings of this study confirmed that EbA activities in the study area played an important role in climate variability. Temperature was reduced while rainfall was increased after intervention with EbA. The respondents said that before implementation of EbA the crops faced different environmental problems including drought for long period of dry season leading to reduction of crop production. There was no sufficient rainfall but nowadays farmers said that EbA contributes significantly on mitigation of climate variability and regulation of climate. This study is in line with other research findings conducted by different scientists e.g. Donatti et al., 2020 who said that EbA activities especially, planting trees plays an important role in minimization of the impacts of drought increasing the quantity of water. Khaniya et al., 2021 reported that trees planted in EbA play an important role in mitigation of climate variability and change. Espeland & Kettenring (2018) highlighted that increase of trees' cover has ability to reduce the effects of temperature and management that rise plant cover reducing desertification effects. Baker (2021) said that the tree planted in agricultural land increase local or regional rainfall reducing temperature, and mitigation

of the future drought. All mentioned evidences confirm that EbA program contributes positively to the climate variability.

The findings of this research highlighted that agroforestry adopted in EbA approach in the study area played a critical role in increase of crop yields. The mean differences were highly significant at 0.01 level with p-value 0.000. This study has similarities with other researchers conducted by Yoseph et al. (2023) highlighting that agroforestry provide different benefits like enhancement of biodiversity and crop yield as well as improved soil health. So, considering on all mentioned evidence the hypothesis said EbA increase crop yield is accepted.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Ecosystem-based Adaptation (EbA) is a nature-based approach that combine both biodiversity and ecosystem services to aid human being to adapt to the unpleasant effects of micro-climate variability and change. In addition, improvement of climate resilience, intervention of Ecosystem based Adaptation can provide different benefits including both environmental and socio-economic. Those benefits include conservation of biodiversity, protection of human beings and helping them to get what they need while mitigating climate change through carbon sequestration and improvement of agricultural productivity. Agroforestry systems as an EbA approach was established in the study area to restore degraded ecosystems for helping people and other organisms to continue gaining benefits from ecosystems. After implementation of EbA, this approach displayed ability to improve crop production where crop yield was increased due improvement of climatic parameters. EbA mitigates climate variability and extreme conditions like heavy rain or droughts as well as change land use from mono-cropping to agroforestry.

5.2. Recommendation

This study recommends to use of EbA approach to help people to resist the impacts of micro-climate variability but also to investigate different factor that help crops to grow well in agroforestry system. This study also recommends to assess the impacts of planted trees through installation of different instruments (thermometers and pluviometer) in the study area to avoid generalization of large area.

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Appendex

1. Questionnaire

a. Identification of the respondent

1. Gender: Male ☐ Female ☐

2. **Marital status:** Single ☐ Married ☐ Widow ☐

3. **Level of education:**

No formal education ☐

Primary level ☐

Secondary level ☐

University level ☐

TVET School ☐

Other (please specify)_____

4. Age: 18-25 ☐ 26-35 ☐ 36-45 ☐ 46 -55 ☐ 56-65 ☐ above ☐

Assess the impacts of EBA intervention on land use practices (forestry, Agroforestry and crop land

1. If you have plot where EBA activities were implemented, how long did you own the plots
   a. Less than 2 years
   b. Between 3-5 years
   c. Between 5 -10 years
   d. Greater than 11 years
2. **Before implementation of EBA, what was the use of land?**
   a. Forestry
   b. Agroforestry
   c. Agriculture
   d. Construction
3. W**hat is the use of your land nowadays?**
   a. Agriculture
   b. Forestry
   c. Pasture
   d. Agroforestry
   e. Construction
4. **Role EBA project in use of Land**
   a. They gave us and planted tree

b. They establish forestry
c. They gave us fruits
d. Other specify.....

5. <u>Answer by Yes or No</u>

a. EBA activities has negative impact on crops (through competition on nutrient, water, light etc)
b. EBA activities increase soil fertility through recycling of nutrient from deep soil
c. EBA activities contribute in soil erosion
d. Trees planted in EBA activities protect plant against heavy wind
e. Implementation of EBA host pest and disease
f. EBA program generate income for farmers
g. EBA activities help farmers to get Fuel wood, stakes
h. If there are other benefits specify

Analyze of the effects of EBA intervention on climate variability in Kirehe District

6. As farmer who spend 5 years in this area, what are the changes did you observed after implementation of EBA

a. Temperature was reduced and crops can not be damaged by temperature

b. Temperature was increased

c. Rainfall is sufficiency

d. Rainfall reduced

e. Rain fall on time

f. There is no drought

g. No changes

7. **What are the environment benefits from EBA?**

a. Change microclimate for crop

b. Provide shade to crop and animals

c. Purification of water and air

d. Mitigation of climate variability

e. Other specific

8. **Answer by "yes", "no" or "I don't know" after understanding the following statement: B**efore implementation EBA

a. Temperature was high resulting crop damage drought

b. There was no sufficient rainfall
c. Water retention capacity resulting wilting of crops
d. Planted trees capture rainfall
e. Other specify

9. What are environmental benefits from implementation of EBA

a. Provide microclimate to crops
b. Provide shade to crops and animals
c. Habitat for biodiversity
d. Purification of water and air
e. Mitigation of climate variability
f. Other specify

Investigate the effect of EBA intervention on crop production

10. How long did you spend growing crops in this area?

a. Less than 2 years
b. Between 3-5 years
c. Between 5-10 years
d. Greater than 10 years

11. In these year you spend growing crop what are your preference crops

a. Maize
b. Banana
c. Cassava
d. Beans
e. Irish potatoes
f. Other specify

12. If you compare yield obtained before and after implementation of EBA, what do observe? Answers question in the table below.

Crops	**Choose yield increased, reduced / no change**	**Yield before (Kg)**	**Yield after (Kg)**
Maize			

Cassava			
Beans			
Irish potatoes			
Other specify			

13. If the yield was reduced, what do you think as cause?

a. Trees compete crops for nutrients, water, sunlight
b. Planted Trees haven't impacts of crops
c. Planted trees are still to small haven't impacts on crop
d. Other specify

14. If the yield was increased, what do you think as the causes (explain the causes)

……

15. What are the challenges, did you face in the implementation of EBA?

……
……

16. How those challenges can be solved?

……
……

17. What can be done so that EBA continue to help you to achieve the development as well as mitigate climate variability?

……
……

INTERVIEW GUIDE

Interview guide reserved for key Informants Interviews

Assess the impacts of EBA intervention on land use practices (forestry, Agroforestry and crop land

1. How long did you spend in implementing EbA activities?

   ……

2. Referring to the time you spend in this area, which changes on land use did you apply?

   ……

3. What are the effects of those changes on land use?

   …….....

4. By comparing before and after implementation of EbA activities, did the farmers proud of those activities? Explain.

   ……

Analyze of the effects of EBA intervention on climate variability in Kirehe District

5. Are there environmental changes occurred due to EbA activities? (eg. Change of precipitation, temperature etc). if there are explain

   …….....

Investigate the effect of EBA intervention on crop production

6. After implementing EbA, what are the changes occurred about agricultural yield

   …….....

7. Referring to some crops suitable to this region, explain the changes of agricultural yield due to EbA activities: ……

8. Basing of your observation, do confirm that EbA activities are sufficient to increase crop yield: ….....

9. Explain if the farmers are proud of implementing and getting benefits from EbA?

   …….....

10. What are the challenges of implementing EbA activities?

    ……

11. If there are different challenges, how do you plan to overcome.: ……