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Climate Change Effects on Agricultural Production and Rural Livelihoods in Rwanda: Gendered Adaptation Strategies from Smallholder Farmers in Bahimba Wetland, Rulindo District.

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Climate Change Effects on Agricultural Production and Rural Livelihoods in Rwanda: Gendered Adaptation Strategies from Smallholder Farmers in Bahimba Wetland, Rulindo District.

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CERTIFICATION

This is to certify that, the thesis entitled "**Climate Change Effects on Agricultural Production and Rural Livelihoods in Rwanda: Gendered Adaptation Strategies from Smallholder Farmers in Bahimba Wetland, Rulindo District**" written by Mrs. Drocella NYIRANGIRIMANA has been done under my guidance and supervision.

Name of the Supervisor:

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Date 07/10/2025

DECLARATION

I, declare that this thesis entitled "**Climate Change Effects on Agricultural Production and Rural Livelihoods in Rwanda: Gendered Adaptation Strategies from Smallholder Farmers in Bahimba Wetland, Rulindo District**" has not been previously submitted for any academic degree or examination at another higher education institution. Additionally, I have properly indicated and acknowledged all the sources I have utilized or quoted by providing complete references.

Date 07/10/2025

Mrs. Drocella NYIRANGIRIMANA

APPROVAL

It is hereby confirmed that this thesis entitled "Climate Change Effects on Agricultural Production and Rural Livelihoods in Rwanda: Gendered Adaptation Strategies from Smallholder Farmers in Bahimba Wetland, Rulindo District"submitted by Drocella NYIRANGIRIMANA has been assessed and accepted for the award of the Degree of Master of Science in Geo-Information for Environment and Sustainable Development, in the School of Architecture and Built Environment.

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Mrs. Drocella NYIRANGIRIMANA

Abstract

This study aimed at assessing the effects of climate change on agricultural production and rural livelihoods in Rwanda with a special focus on the existing gendered adaptation strategies from smallholder farmers in Bahimba Wetland, Rulindo District. Data were obtained using different methods and techniques of data collection including review of existing published and unpublished reports, analysis of meteorology data, field observation, household questionnaire and interviews. For data analysis, SPSS, Microsoft Excel and geospatial software were used. Drawing on household-level data, the study reveals that 71.6% of respondents are aged 31–65 and 59% are women. Most farmers (80%) possess only primary-level education or less, and 99% rely solely on farming as a livelihood. Despite climate shifts especially in rainfall patterns (reported by 92.6%) adaptive capacity remains low, with 83.2% of respondents citing a lack of knowledge and 88.4% having received no external support. Women, while leading 57.9% of farming activities, face significant barriers: limited decision-making power (67.9% report only partial involvement), inadequate access to training (8.4%), and low credit access (40% lack financing). While 92.6% report equal land access in theory, gender disparities persist in practice. The most common adaptation strategy is altering planting dates (83.2%), while more effective, resource-intensive methods remain underused. Policy findings emphasize the need for gender-separate adaptation strategies, endorsed by all respondents. Recommended interventions include strengthening women's access to climate services, promoting labour-saving technologies, supporting diversified income sources, and addressing systemic inequities in land tenure and education. The study concludes that effective adaptation in Rwanda's wetlands must be gender-responsive, context-specific, and structurally transformative to ensure long-term resilience and food security.

Keywords: *Climate Change Effects, Smallholder Farmers, Gendered Adaptation Strategies, Bahimba Wetland & Rulindo District.*

List of Acronyms

CC	Climate Change
CSA	Climate-Smart Agriculture
DRR	Disaster Risk Reduction
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GGCRS	Green Growth and Climate Resilience Strategy
GHG	Greenhouse Gas
IPCC	Change Intergovernmental Panel on Climate Change
MIGEPROF	Ministry of Gender and Family Promotion
MINEMA	Ministry in Charge of Emergency Management
NAP	National Adaptation Plan
NDRRM	National Disaster Risk Reduction and Management Policy
NECCP	National Environment and Climate Change Policy
NECCP	National Environment and Climate Change Policy
NGOs	Non-governmental Organizations
NLUDMP	National Land Use and Development Master Plan
NST2	National Strategy for Transformation 2
PSTA 4	Strategic Plan for Agriculture Transformation
REMA	Rwanda Environment Management Authority
SDGs	Sustainable Development Goals
UN	United Nations
WHO	World Health Organization

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Chapter 1: Introduction

1.1 Background Information

Across the world, farmers are increasingly affected by changing climatic conditions (Anderson et al., 2020; Karki et al., 2020). This is particularly true for the nearly 600 million smallholder farmers who rely on family labour for food production and livelihoods (Moore, 2023; Moore & Niles, 2024), many of whom depend on rain-fed agriculture. Climate change disproportionately impacts women, who often bear heavier household responsibilities while facing limited access to resources, technology, and climate information (Fierros-González & López-Feldman, 2021). These constraints reduce their efficiency in agricultural production and adaptation to climate change. Additionally, restricted access to labour-saving technologies, such as animal traction and improved transport, further hinders their ability to respond effectively to climate-related challenges (Jerneck, 2018; Raza et al., 2019).

In developing countries, smallholder farmers are particularly vulnerable to climate change due to their reliance on rain-fed agriculture as the primary source of food production. However, these impacts are not experienced equally among different socioeconomic groups (Chepkoech et al., 2020; Ndebele & Zenda, 2023; Ojo et al., 2024). In East Africa, small-scale agricultural production is already under significant pressure. Farmers in the region face challenges such as land scarcity, declining soil fertility, and poor market access, all of which contribute to low crop yields and increasing food insecurity. Additionally, a growing population places further pressure on agricultural systems, making rural communities highly susceptible to climate variability. Changes in rainfall patterns and temperature fluctuations are drastically altering the functioning of agricultural landscapes, often leading to destructive outcomes (Omotoso et al., 2023).

As a result, East African farmers must adapt their agricultural practices to enhance resilience and strengthen their adaptive capacity. Adaptive capacity refers to a community's ability to reorganize itself in response to climate change without experiencing significant disruptions in function. It is closely linked to the ability to learn, innovate, and collaborate to maximize shared benefits. Climate resilience, on the other hand, is the capacity of both people and ecosystems to withstand, recover from, and thrive in the face of climate-related shocks (Ackerl et al., 2023). In rural agricultural-dependent communities, climate resilience encompasses ecological, social, and economic dimensions, which are often shaped by farmers' perceptions of climate change (Bryant et al., 2016). The ways in which men and women experience climate change differ due to their distinct roles and responsibilities within farming communities. Gender inequality further compounds the challenges faced by women, limiting their adaptive capacity and influencing their decision-making regarding climate adaptation strategies (Mehar et al., 2016).

In addition, the contributions of smallholder women farmers to global and household food security are gaining increasing attention of policy makers worldwide. Among the many challenges facing smallholder women farmers in their food production are weather and climate extremes (Boansi et al., 2017; Mulwa et al., 2017; Mulwa & Visser, 2020; Owusu & Waylen, 2013). Notably, farmers in sub-Saharan Africa (Annappa et al., 2023) have received the biggest brunt of weather extremes because of their over-dependency on rain fed agriculture (Owusu & Waylen, 2013). Wrigley-Asante et al. (2019) pointed out that the high frequency, intensity and duration of floods and droughts have had deleterious implications on food crop production of women farmers in Rwanda. Smallholder women farmers have become the most vulnerable to climate extremes and related risks (Owusu & Yiridomoh, 2021) due to their unequal access to land and financial resources (Huyer, 2016a), lack of productivity enhancing inputs (Wrigley-Asante et al., 2019) and limiting institutional and infrastructural barriers on their use of climate information (Carr et al., 2016; Hansen et al., 2019; Wrigley-Asante et al., 2019). The unequal access to resources by women farmers tends to lower their adaptive capacity (Huyer, 2016a; Nyantakyi-Frimpong, 2021; Wrigley-Asante et al., 2019). The Sustainable Development Goals (SDGs) of ensuring no poverty (Goal 1), zero hunger (Goal 2), gender equality (Goal 5) and climate action (Goal 13) in low-income countries emphasize on the need for women farmers to respond to the adverse impacts of weather and climate extremes (SDG, 2017). The climate extreme in most cases may be covariate in nature (e.g. droughts, floods, bush fires or tropical storms), and farmers within a particular region may be exposed to them. The negative effects of the climate extremes may be different, but the adaptive capacity depends on the individual farmers.

Generally, in Rwanda, over 80% of the population is engaged in agriculture and rural livelihood depend on it, which contributes approximately 32% of the country's GDP (Bizimana et al., 2012).

However, agriculture in Rwanda faces numerous challenges, including land scarcity, high population densities, and small median landholdings of about 0.3 hectares per household (Bigagaza et al., 2002). Smallholder farmers dominate agricultural production, requiring tailored extension services to meet their needs (Alexis, 2022; William, 2018). Additionally, Rwanda's landlocked status results in higher energy and transportation costs compared to neighbouring countries. The country's unique topography, with diverse landscapes and microclimates, further influences agricultural productivity and vulnerability to climate change.

Rural Rwandan population's climate variability plays a significant role in shaping gendered experiences of agricultural challenges. Climate-related risks, particularly those affecting food production, have drawn increased attention in recent years (Huggins, 2017). In Rwanda, rainfall patterns directly influence the water regimes of fields and wetlands, making them critical determinants of crop productivity and food security. For instance, in 2004, excessive rainfall in high-altitude regions, which are typically more productive, led to a sharp decline in legume production. Furthermore, Rwanda's rugged topography makes it highly susceptible to erosion and landslides, amplifying the adverse effects of climate hazards (Jonah et al., 2021). Although, the adaptation strategies that smallholder farmers use in response to climate extremes could be ex-ante or ex-post (Shiferaw et al., 2014; Abid et al., 2020). Ex-ante adaptation strategies are necessary risk-mitigating strategies, even if the climate risks do not occur. Ex-post adaptation strategies are often used to target specific climate extremes after exposure to those risks. There are myriads of studies on adaptation strategies that farmers use in response to climate extremes in SSA. In Rwanda, some of the ex-ante adaptation strategies that women farmers use in response to climate extremes include changing of time of planting, use of soil erosion tolerant and early maturing crop varieties and switching to crops that are less sensitive to climate stress (Tambo, 2016; Adzawla et al., 2019). Women farmers also use row planting, mixed farming, intercropping and refiling of farm plots (Adzawla et al., 2019). They also use a combination of subsistence agriculture, livestock rearing, seasonal or long-term, migration, and localized natural resource extraction (Lawson et al., 2020).

Smallholder farmers, particularly those in the Bahimba wetland, experience severe climate change effect triggered by heavy rainfall during the rainy season. Soil erosion and flooding frequently damage valley crops, leading to significant losses for both men and women farmers. Given these challenges, this study seeks to explore climate change adaptation strategies from a gendered perspective, focusing on smallholder farmers in Bahimba wetland. The research will assess how gender influences climate change adaptation and resilience, ultimately contributing to more inclusive and effective climate policies in Rwanda.

1.2 Problem Statement

Rwanda has experienced severe climate change-induced disasters, including heavy rains, droughts, floods, landslides, and cropland damage (Niyonsaba, 2016). Between 1980 and 2017, these extreme weather events affected more than one million people, leading to fatalities, wounds, homelessness, and extensive loss of livelihoods. Approximately 15,000 hectares of cropland were damaged, and 23,000 houses destroyed, severely impacting rural communities that depend on agriculture for subsistence and food security (Nahayo et al., 2019).

The intersection of climate change, gender inequality, and agricultural vulnerability presents a complex and understudied challenge for smallholder farmers in Rwanda, mostly in rural wetlands such as Bahimba, Rulindo District (Nyasimi et al., 2018). Women, who make up the majority of smallholder farmers, bear a disproportionate burden of climate-related shocks due to pre-existing gender disparities in access to land, finance, extension services, and decision-making platforms. As the climate crisis intensifies with erratic rainfall, soil erosion, and frequent flooding—the gendered impacts become more evident. These environmental challenges threaten not only agricultural productivity but also aggravate poverty, diminish food availability, and strain the coping capacities of women farmers who are often responsible for both household food provision and income generation (Tirivangasi & Nyahunda, 2019).

In the Bahimba wetland, climate change has led to intensified rainfall during the rainy season, resulting in flooding, surface runoff, and soil erosion. These events have degraded farmland and reduced yields over time. The absence of effective slope management and wetland protection measures has advance accelerated environmental degradation. Although both men and women farmers are affected, women's adaptive capacity is critically constrained due to mechanical barriers such as limited access to agricultural inputs, credit, land tenure rights, and technical information.

While existing studies have focused on climate variability and its impacts on agriculture in Rwanda (Mikova et al., 2015; Mutabazi, 2010; Ngarukiyimana et al., 2021); Rwanyiziri et al. (2019), none have adopted a gender-sensitive lens. Furthermost current literature lacks a detailed understanding of how men and women differently perceive climate threats or adopt adaptation strategies, particularly in vulnerable in wetlands. This leaves an importantly knowledge gap in designing equitable and context-specific responses to climate change.

Therefore, this study aims to fill this gap by investigative climate change effects on agricultural production and rural livelihoods and gendered Adaptation Strategies from Smallholder Farmers in Bahimba Wetland. It will explore how women and men perceive climate-related risks, the differentiated impacts they experience, and the coping strategies they employ. By foregrounding gender, the study intends to inform more inclusive, effective, and sustainable adaptation policies that strengthen the resilience of marginalized rural communities.

1.3 Research Objectives

This study was guided by both the main objective and specific objectives.

1.3.1 General Objective

To assess the gendered adaptation strategies to climate change effects among smallholder farmers in Bahimba wetland.

1.3.2 Specific Objectives

Specifically, this study was guided by the following objectives:

1. To describe major indicators of climate change and their adverse effects on agricultural production in the study area of Bahimba wetland.

2. To assess the extent to which smallholder farmers are vulnerable to climate change effects and the impacts on rural livelihoods with a focus on gender dimension.

3. To propose gendered approaches adaptation strategies to reduce impacts of climatic change on smallholder farmers in Bahimba Wetland.

1.4 Research Questions

This study was guided by the following research questions:

1. What are the major indicators of climate change in the Bahimba Wetland, and how do they adversely affect agricultural production?
2. To what extent are smallholder farmers in Bahimba Wetland vulnerable to climate change effects, and how does this vulnerability differ by gender?
3. What gender-responsive adaptation strategies can be proposed to reduce the impacts of climate change on smallholder farmers in the Bahimba Wetland?

1.5 Theoretical and Conceptual Framework

The research explains key concepts, variables, and their relationships. These explanations serve as a foundation for understanding and analysing a specific research topic or problem. The conceptual framework in Figure 1 illustrates the interconnected dynamics influencing how gender shapes adaptation to climate change among smallholder farmers in the Bahimba Wetland, Rulindo District. At the center is the core research issue: "Adaptation to Climate Change Effects: Gender Approach from Smallholder Farmers". This central theme is approached through three key dimensions Social Capital, Sustainable Livelihoods, and Gender Mainstreaming each representing critical factors that mediate how men and women respond to climatic impacts on agriculture and rural life.

The Social Capital dimension encompasses institutional and community support systems, such as gender-sensitive policies and collective climate actions. This component highlights the importance of including women in climate decision-making, improving food security, and strengthening the resilience of vulnerable groups. Policies that empower women and encourage inclusive governance structures are vital for equitable adaptation, especially in areas like Bahimba where local norms and institutional barriers often restrict women's participation in agricultural planning and climate resilience programs.

Sustainable Livelihoods focuses on the gendered impacts of climate change on agricultural production and food security. It reflects how exposure to climate hazards such as erratic rainfall, soil erosion, or crop failure affects men and women differently due to unequal access to resources, decision-making power, and livelihood responsibilities. For example, while women may bear the burden of household food provision, men often dominate decisions in cash crop production. Recognizing these distinctions is essential to designing adaptive interventions that improve resilience while addressing inequalities in productivity and income.

1.6 Motivation and Significance of the Study

Climate change poses an escalating threat to agricultural productivity and rural livelihoods globally, with particularly severe consequences in vulnerable regions such as Rwanda. In Rulindo District, smallholder farmers in the Bahimba Wetland face increasing exposure to erratic rainfall patterns, frequent floods, and accelerated soil erosion all of which jeopardize crop yields, food security, and income stability. Agriculture being the primary livelihood in the region, the effects of climate variability directly undermine the resilience and well-being of these communities. Among the most affected are women farmers, who often lack access to the necessary resources, knowledge, and decision-making power needed to effectively respond to climate-induced challenges.

This study was motivated by the critical need to understand how gender influences climate adaptation strategies among smallholder farmers in Bahimba Wetland. Gender shapes the way agricultural resources are accessed, managed, and distributed, making it a pivotal factor in adaptation capacity. Despite their significant roles in food production and resource stewardship, women are frequently excluded from adaptation planning and support mechanisms. By examining the gendered dimensions of climate change impacts and responses, this research will contribute to more inclusive and effective climate adaptation strategies that recognize the unique vulnerabilities and strengths of both men and women in agricultural communities.

The significance of this study lies in its potential to inform local policy and community-based interventions aimed at enhancing climate resilience. By documenting the specific adaptation, strategies employed by farmers in Bahimba Wetland particularly women the research provides practical insights for developing gender-responsive and locally grounded solutions. These findings will support local authorities and development partners in designing programs that not only promote sustainable agricultural practices but also empower smallholder farmers to secure their livelihoods amidst a changing climate. In doing so, the study aligns directly with the broader objective of strengthening rural resilience and ensuring equitable adaptation in the face of climate change in Rwanda.

Chapter 2: Literature Review

This chapter summarizes the information extracting from the different researchers. It is including Concepts of Climate change and Smallholders, the gender-specific impacts of climate change, particularly rainfall variability and soil erosion on smallholder farmers, the key factors influencing smallholder farmers' perceptions and adaptation to climate change and gender adaptation strategies to reduce impacts of climatic change on smallholder farmers.

2.1. Concepts of Key Concepts and Terminologies

The key concepts of this study include climate change, climate adaptation, smallholder farmers. Gender Approach, Climate variability, Climatic vulnerability, Greenhouse Effect and climate resilience

- **Climate change** refers to long-term shifts and alterations in temperature, precipitation, wind patterns, and other elements of the Earth's climate system. It is primarily driven by human activities, particularly the emission of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which trap heat in the atmosphere. Natural factors, including volcanic eruptions, variations in solar radiation, and oceanic changes, can also contribute to climate fluctuations. The consequences of climate change include rising global temperatures, sea-level rise, more frequent and intense weather events, and disruptions to ecosystems and biodiversity (IPCC, 2007).

- **Climate adaptation** refers to the process of adjusting to actual or expected climate change and its effects. It involves implementing strategies, policies, and practices to minimize the negative impacts of climate change while taking advantage of any potential opportunities. Adaptation measures can be reactive (responding to climate impacts as they occur) or proactive (planning in advance to reduce future risks) (IPCC, 2022a).

- **Smallholder farmers** are individuals or households engaged in agricultural production on relatively small plots of land, primarily for subsistence or local markets. They typically rely on family labour, traditional farming techniques, and have limited access to capital, technology, and markets. The size of a smallholder farm varies by region, but it is generally considered to be less than 2 hectares (FAO, 2014).

- **Gender Approach** refers to a framework that analyses the social, cultural, economic, and political roles and relationships between men and women. It focuses on identifying and addressing gender-based inequalities, ensuring that policies, programs, and initiatives promote gender equity and equality. This approach considers how power dynamics, societal norms, and institutional structures influence gender relations and seeks to create transformative changes that benefit both men and women (Center UN Women Training, 2017). A gender approach is widely used in fields such as development studies, sociology, policy-making, and environmental sustainability to promote inclusivity and equal participation. It incorporates gender mainstreaming, which ensures that gender perspectives are integrated into all levels of planning and decision-making (Reeves & Baden, 2000).

- **Climate variability** refers to the natural fluctuations in climate conditions, such as temperature, precipitation, and wind patterns, over short- to medium-term periods (months, years, or decades). It differs from climate change, which refers to long-term, persistent shifts in climate patterns. Climate variability includes both short-term fluctuations (such as seasonal changes and El Niño/La Niña events) and decadal variations (such as the Pacific Decadal Oscillation). These variations are influenced by both natural factors (e.g., volcanic eruptions, ocean currents, solar radiation) and human activities (e.g., land use changes, greenhouse gas emissions). Understanding climate variability is crucial for environmental management, disaster preparedness, and adaptation strategies, especially in sectors like agriculture, water resources, and biodiversity conservation (Morales, 2022).

- **Climatic vulnerability** is used to describe how vulnerable a system, group, or individual is to the negative consequences of climate variability and climate change, or how unable they are of overcoming them. It takes into account both the ability to respond and adapt as well as the vulnerability to climate-related risks (such as droughts, floods, severe temperatures, or rainfall variability) (Birch, 2014; Change, 2007; Füssel & Klein, 2006).

- **Climate resilience** is the capacity of a system, community, or individual to anticipate, prepare for, respond to, and recover from the adverse effects of climate change—including extreme weather events and long-term climate shifts—in ways that preserve or enhance well-being, sustainability, and adaptive capacity (IPCC, 2022b; USAID, 2014).

- **Greenhouse Effect**: The Earth's atmosphere traps some of the Sun's energy, keeping the planet warm enough to sustain life. Human activities have intensified this natural effect by adding more greenhouse gases (like CO_2, CH_4, and N_2O), leading to global warming (IPCC, 2021; NASA, 2022).

2.2. Major Indicators of Climate Change and their Effects on Gender Issues

The major indicators change is very curial important in Rwanda. These includes increasing temperature trends and changes in rainfall patterns and seasonality.

2.2.1. Major Indicators of Climate Change in Rwanda

2.2.1.1. Increasing Temperature Trends in Rwanda

One of the most evident indicators of climate change in Rwanda is the observed increase in average temperatures over recent decades. The Rwanda Meteorology Agency reports that the country's average annual temperature has risen by approximately 1.4°C since 1970 (Mirindi, 2022). This warming trend is consistent with global climate change patterns and has significant implications for agriculture, health, and biodiversity.

The increase in temperature exacerbates the frequency and intensity of heatwaves, especially in low-altitude areas such as the Eastern Province. This poses risks to human health and livestock, increasing vulnerability to heat stress and reducing productivity. For instance, farmers in Bugesera District have reported decreased milk production due to heat stress on dairy cattle (REMA, 2019).

Higher temperatures also affect crop yields by accelerating evapotranspiration, leading to soil moisture loss and plant stress. Crops such as maize and beans, which are staple foods in Rwanda, are particularly sensitive to temperature fluctuations. This threatens food security and the livelihoods of smallholder farmers who rely on rain-fed agriculture (Nyirakanani et al., 2021).

Moreover, rising temperatures have ecological consequences. They disrupt the life cycles of certain insects and pests, such as the fall armyworm, which now thrives in warmer conditions, causing widespread crop destruction. These shifts underscore the urgent need for climate adaptation strategies that account for increasing temperature trends in Rwanda.

2.2.1.2. Changes in Rainfall Patterns and Seasonality

Altered rainfall patterns are another prominent indicator of climate change in Rwanda, affecting both the timing and intensity of seasonal rains. Historically, Rwanda had two well-defined rainy seasons: March to May and September to December. However, recent data indicate growing unpredictability, with shorter rainy seasons, delayed onsets, and erratic rainfall (Abrego-Perez & Guizar, 2018).

These changes disrupt agricultural calendars, leading to poor crop germination and reduced harvests. For example, in the Northern Province, farmers have experienced challenges planting Irish potatoes due to unpredictable rains that either arrive late or cause flooding. This variability undermines the reliability of traditional farming knowledge and necessitates new climate-smart agricultural practices (Kumar, 2021).

Additionally, extreme rainfall events have become more common, contributing to severe floods and landslides in mountainous areas. Districts like Nyabihu, Musanze, and Rubavu have experienced repeated flood-related disasters, displacing families and damaging infrastructure. In May 2023, heavy rains killed over 130 people and destroyed hundreds of homes in Western and Northern Rwanda (MINEMA, 2023). The irregularity of rainfall also affects water availability for both domestic and agricultural use. Rivers and wetlands experience fluctuations, leading to water stress in dry periods and erosion in wet periods. Consequently, water resource management is increasingly critical as rainfall patterns continue to deviate from historical norms.

2.2.2. Gender-specific Impacts of Climate Change in Rwanda

The gender specific impacts of climate change in Rwanda including impacts on agriculture production, Impact on Food and Nutrition Security, Impact on Health, Impact on Water and Energy

2.2.2.1. Impact on Agricultural Production

Increased climate variability lowers agricultural productivity, frequently with disparate effects on the financial, social, natural, physical, and human assets of men and women. For instance, women in the Sahel fear that greater climate variability will deny them access to rangeland and other resources needed for livestock production (Goh, 2012). It has been demonstrated that changes in the crops that farm households cultivate in response to climatic change affect decision-making involvement, labour division, and crop income control. For instance, in East Africa, commercialization tends to erode women's power by concentrating on sales rather than consumption decisions, even if it has been recognized as a crucial tactic in helping farmers adapt to climate change (Tavenner et al., 2019). (Walker et al., 2002) demonstrate how the composition of herds in response to drought is defined by a change from cattle or camels to sheep and goats, which are under the care of women. This results in a greater amount of work and responsibility for women than for men.

Households in southern Tanzania are being forced to cultivate additional land, which requires more labour, due to rising rainfall variability, deteriorating soil fertility, yield variability, and declining crop yields (Nelson & Stathers, 2009). Voluntary seasonal migration among male household members seeking off-farm job is imposing increasing pressure on women who must assume enlarged domestic tasks in the absence of male members of the household. Furthermore, because women must shoulder the majority of the replanting work, the necessity to do so more frequently due to unpredictable rains puts more strain on their time. Research indicates that diversifying crops and livestock in response to climate change increased revenue (Makate et al., 2016) and food and nutrition security (Snapp & Fisher, 2015) for smallholder farm households.

However, Kristjanson et al. (2017) demonstrate how the use of agricultural technology and crop diversification greatly raised the demand for agricultural labour among Ethiopian women, taking time away from childcare and food preparation. Previous studies Maertens et al. (2012) showed that increased labour demand for female heads of the household has a negative impact because girls are removed from school to replace their mothers in gender-determined household activities. Women have poor access to training, extension services, and technology necessary for effective adaptation to the impacts of climate change (Witinok-Huber et al., 2021). Furthermore, barriers to women's use of technology are visible at all phases of the adoption process, including awareness, testing, and ongoing adoption (Oyetunde-Usman et al., 2021).

A comparative study of women's access to rice-producing technology in Tanzania, Madagascar, and Ethiopia revealed that institutional and cultural variables impeded uptake (Achandi et al., 2018). Furthermore, women's time and spatial mobility limitations greatly influence how they interpret climate and weather forecast information (Goh, 2012). Survey data from Kenya (Auma et al., 2010) showed that the total value of farming equipment owned by female-headed families was less than half that of male-headed households. Low fertilizer application rates are linked to households headed by women in response to input shortages.

In north-eastern Ethiopia, for instance, families headed by men were almost 52% more likely than those led by women to employ organic fertilizer (Sachs, 2023). discovered no proof of a gender disparity in abilities after adjusting for input availability, especially for soil quality, indicating that women face disproportionate disadvantages. Female-headed families' agricultural production is substantially more sensitive and less climate change-adaptive due to their relatively low endowments in key productive inputs like land, labour, and capital. Social norms and traditional gender roles, especially caregiving undermine women’s capacity to reallocate time to work on family plots, diversify crop or livestock production or take up off-farm work (Havlík et al., 2015). Certain societies restrict access to markets or the ability to grow specific crops to men only. Additionally, many adaptation strategies are expensive for households with limited credit availability and few, primarily female, working-age adults since they need expenditures in labour, time, technology, inputs, and networks for collective action like cooperatives. Access to weather and climate information as well as investment needs and goals may be impacted by gender and socioeconomic disparities between men and women.

2.2.2.2. Impact on Food and Nutrition Security

At the home level, climate change has an impact on nutrition, diet quality, food production, and food availability and access all at once. Floods, droughts, and land degradation are just a few of the direct and indirect ways that climate change will impact food availability, access, and nutritional security. Indirect effects include income shocks and health consequences brought on by the increased viability of pathogenic microbes and their vectors (Sorensen et al., 2022). However, men and women are not equally affected by climate change's negative consequences on food and nutrition security. Women will be disproportionately affected by climate-induced food and nutritional insecurity in areas with high levels of food insecurity, such as sub-Saharan Africa, because of their vulnerability to socially imposed gender roles and restricted access to resources (Botreau & Cohen, 2020; IPCC, 2014).

Reduced crop yields and crop failure, animal loss, increasing water shortages, and damage of other productive assets are some of the concerns associated with climate change that affect the security of food and nutrition. Climate variability poses a risk to crop and animal systems, and extreme occurrences like drought, floods, disease outbreaks, and heat stress can cause harm (Jones & Thornton, 2009). According to research, the detrimental effects of climate change on women's and female-headed households' food and nutrition security are made worse by prevailing social, institutional, and structural biases and impediments (Weiler et al., 2016).

Crop yields that provide vital minerals like calcium, folate, thiamine, and pyridoxine all of which are critical during pregnancy are reduced by extreme weather events (Leroy et al., 2020). Malnutrition among mothers may directly worsen as a result of climate change. Unreliable rainfall has an impact on rural households' capacity to feed their families in rain-fed farming systems. Maternal malnutrition exacerbates the negative effects of infectious diseases on the health of the mother, fetus, new-born, and kid. In a thorough analysis of the literature, (Salm et al., 2021) demonstrate how the effects of climate change caused women to suffer from malnutrition because they frequently skipped meals to provide food for other family members when they were hungry and had to go farther to get fuel and water (Salome, 2016) demonstrated that when food shortages were common in north-eastern Kenyan villages, women would often cut back on their food intake to ensure that the male household members had enough to eat. Children under the age of five who are born during drought have a 36–50% higher risk of malnutrition in Ethiopia and Kenya, two of Eastern Africa's most drought-prone countries (Smith et al., 2014).

In measuring the impact of climate and weather variability on gender and food security, (Périlleux & Szafarz, 2015) demonstrate that although weather-related crop failure brought on by insufficient rainfall, wind, or hailstorms lowers food consumption levels for all households, the decrease was significantly larger for homes with women who are widowed, divorced, separated, or single. Moreover, (Périlleux & Szafarz, 2015) found that homes headed by women were more likely to experience food insecurity, and that there was a statistically significant difference in consumption between male and female-headed households of up to 21%. This is in line with previous research that found households headed by women were more susceptible to weather and climate change (Deaton & Dreze, 2002)

2.2.2.3. Impact on Health

Tadesse (2010) claims that the benefits of public health will be undermined by climate change, particularly in Africa, where the effects of climate change on health will be seen in the form of increased viability of pathogenic microbes and their vectors, exacerbated chronic diseases that are sensitive to the environment, reduced water quality, and malnutrition brought on by drought-induced food insecurity (Sorensen et al., 2018). Socioeconomic disparities function as a mediator and magnifier for the direct and indirect effects of climate change on women's health. Moreover, physiological, cultural, and socioeconomic variables convey gender disparities in the health effects of climate change. Particularly during pregnancy and lactation, women are more susceptible to climate-induced changes in food and nutrition security and are more likely to experience chronic malnutrition (Sorensen et al., 2018). Additionally, infectious diseases have more serious consequences on maternal-fetal and child health, an effect that is amplified by maternal malnutrition (Blakstad & Smith, 2020). (Thiede et al., 2022) have demonstrated that women who are exposed to periods of higher-than-normal temperatures and lower-than-normal precipitation have a much lower chance of becoming pregnant the following year. (Grace et al., 2012) have demonstrated that women who are exposed to periods of higher-than-normal temperatures and lower-than-normal precipitation have a much lower chance of becoming pregnant the following year.

Helldén et al. (2021) have demonstrated direct economic consequences of drought on women; from diminishing household assets to food insecurity, to increased risk of poor sexual and reproductive health outcomes. Extreme events and natural disasters globally are projected to become more severe because of climate change. (Neumayer & Plümper, 2007) demonstrated that women experience disproportionately higher mortality rates during climate-induced disasters due to gender-specific exposure and vulnerability that are determined by cultural and societal factors and ingrained in regular socioeconomic patterns. More women than men perish in some famines, such as the one in Ethiopia in 1984–1985, either as infants or at a very early age, mostly as a result of unequal access to food supplies. Additionally, women who give birth during or soon after a natural disaster are more likely to experience negative reproductive outcomes, such as haemorrhage, an early delivery, problems during delivery, and preeclampsia, a condition in which a pregnancy is marked by high blood pressure and damage to essential organs (Tong et al., 2011; WHO, 2002).

Rising temperatures and changes in rainfall patterns may contribute to increased malaria transmission in sub-Saharan Africa. About 55% of the world's malaria cases occur in Nigeria, the Democratic Republic of the Congo, Uganda, Mozambique, Angola, and Burkina Faso (World Bank, 2012). Malaria infections during pregnancy led to 819,000 low-birth-weight babies in the 33 countries that make up West Africa, Central Africa, and East and Southern Africa (World Bank, 2012). Pregnant women are thought to have a roughly 50% fatality rate from malaria infections, and they are three times more likely than non-pregnant women to get a severe sickness from them. Additionally, there was a greater than twofold chance that children born to moms who had placental malaria would be underweight at delivery. The majority of low birth weight children do well, but collectively they are more likely to experience subnormal growth, diseases, and issues with attention, cognition, and neuromotor functioning (Hack et al., 2009).

As a result, low birth babies' long-term developmental outcomes raise the caregiving load on female family members and may reduce a mother's time for other productive pursuits, making the entire household more vulnerable. Their labour output is reduced by malaria, which also disrupts the production cycle and diverts resources away from agricultural inputs. According to (Girardin et al., 2004), farmers who reported being ill with malaria for an average of 4.2 days during a single cabbage production cycle recorded 47 percent lower yields and 53 percent lower earnings than farmers who reported being ill for an average of 0.3 days. According to (Fink & Masiye, 2015), Zambian farmers who had access to bed nets saw a significant improvement in production as a result of preventative health investments; harvest value rose by 14.7% of the average output value.

2.2.2.4. Impact on Water and Energy

Africa is the second driest continent in the world, after Australia, with only 9% of the world's renewable water resources. a reduction in precipitation overall in the continent's southern and northernmost regions. The hydraulic cycle is predicted to be impacted by climate change, endangering water security, which is essential for fostering health and wellbeing (Niang et al., 2015). Sociocultural norms regarding the division of labour, particularly for water collection, are linked to women's vulnerabilities to an inadequate supply of water for domestic usage, particularly during the dry season (Niang et al., 2015).

This lack of access to clean water and energy sources has been linked in studies to increased disease rates, lost social, educational, and economic possibilities, and a generally reduced quality of life. For instance, according to Graham et al. (2016), between 46 and 90 percent of adult females in 24 sub-Saharan African nations were primarily responsible for collecting water, a task that took up more than 30 minutes of their time. Furthermore, 62 percent of female children and 38 percent of male youngsters in all 24 countries which include Liberia, Cote d'Ivoire, Nigeria, Niger, Ethiopia, Burundi, and Mozambique were in charge of gathering water. According to research by Pickering and Davis (2012), a 15-minute reduction in the one-way trip time between home and the water source might result in an 11% decrease in under-five mortality and a 41% decrease in the prevalence of diarrhoea. People who already face energy insecurity are particularly impacted by climate events because they are less equipped to handle them.

Climate change also increases cumulative risk and the direct and indirect health consequences of energy insecurity. About 85% of the 6.8 Mt of fine particulate matter (PM2.5) that were released in Africa in 2018 came from domestic biomass burning for cooking and lighting (Bawakyillenuo et al., 2021). Household air pollution (Nyahunda & Tirivangasi, 2021), which is linked to a number of morbidities such as acute chronic respiratory disease, low birth weight, cardiovascular diseases, and cataracts, is mostly caused by particulate matter (Gordon et al., 2014). (Okello et al., 2018)used data on 24-hour personal exposure to HAP from individuals in Ethiopia and Uganda to demonstrate that adult females had the greatest PM2.5 exposure concentrations (177 to 205 µg/m3), while young men had the lowest values (26.3 to 30.3 µg/m3). In the same study, (Okello et al., 2018) found that women who cooked with animal dung had a median PM 2.5 exposure of 276.1 µg/m3, which was lower than the exposures of women who cooked with wood and crop wastes, respectively, of 185.7 µg/m3 and 119.9 µg/m3. During the period between 11 am and 2 pm, when rural women prepare their meals, (Okello et al., 2018) found that the greatest hourly median PM2.5 concentrations ranged from 308 to 386 µg/m3.

Women's health can be adversely affected by water and fuelwood collecting work, which puts a heavy burden on metabolism and damages the musculoskeletal system, which can result in the early onset of arthritis (Fisher et al., 2017). In addition to introducing novel degradation patterns, climate change will accelerate and intensify current land degradation processes. Therefore, for hundreds of millions of women and girls, the already insecure family water and energy situation is made worse by land degradation and climate change, both alone and together, frequently with serious health and livelihood repercussions.

2.3. Vulnerability to Climate Change in Rwanda

Rwanda is highly vulnerable to climate change due to its reliance on rain-fed agriculture, small landholdings, and hilly terrain. Over 70% of the population depends on agriculture, most of which is subsistence-based and covers less than one hectare per household (MINAGRI, 2022). This dependence, coupled with steep slopes prone to soil erosion, increases sensitivity to unpredictable weather, making yields susceptible to rainfall variability, landslides, and droughts (REMA, 2021). The economic cost is significant: floods and landslides in May 2023 destroyed over 3,000 ha of farmland and displaced tens of thousands, exacerbating food insecurity and economic vulnerability (UNDRR, 2023).

Smallholder farmers experience these impacts unevenly, with wealthier households able to adopt climate-smart solutions like irrigation, high-yield seeds, and commercial agriculture while poorer farmers lack access to capital, land, and social safety nets (World Bank, 2020b). For example, rice growers in Bugesera reported 90% reduced yields, while 52% invested in irrigation and 25% used drought-resistant varieties to adapt (FAO, 2022). Meanwhile, the deactivation of traditional risk-sharing institutions has further strained poor farmers' ability to cope, often forcing them into debt or off-farm labour roles to survive. Adoption of gender-sensitive adaptation strategies is slowly emerging, given Rwanda's progressive policies on land inheritance and female land rights (Republic of Rwanda, 2019). Still, women face systemic challenges in accessing finance, technology, and value chains limiting their ability to implement sustainable practices and grow income-generating crops (CARE Rwanda, 2020). Nevertheless, participatory climate services and community-based initiatives, such as crops diversification, terracing, tree-planting, and irrigation schemes, are empowering female smallholders to take on adaptive measures (Women, 2021). These gendered strategies reflect the critical intersection between gender, resilience, and climate change adaptation in rural Rwanda.

2.4. Existing Policy Frameworks on CC and Gender Dimension in Rwanda

2.4.1. Existing Development Orientations

Rwanda's development trajectory is explicitly guided by a cohesive set of policies and strategies that integrate climate resilience, agricultural transformation, and gender equality as fundamental pillars. The overarching National Strategy for Transformation (NST2) 2024-2029 and Vision 2050 establish the core objective of achieving sustainable, climate-resilient, and inclusive socio-economic development. Within this framework, the Revised Green Growth and Climate Resilience Strategy (GGCRS) 2022 and the National Environment and Climate Change Policy (NECCP) 2021 provide the specific roadmap for climate action. These policies explicitly recognize the severe threats climate change poses to agricultural production and rural livelihoods – including increased frequency of droughts, floods, and erratic rainfall and prioritize adaptation measures like climate-smart agriculture (CSA), sustainable land management, water harvesting, and diversification of income sources. Critically, the NECCP (2021) mandates the integration of climate change adaptation and mitigation into all sectoral planning and budgeting, directly impacting agriculture, while the GGCRS (2022) emphasizes building resilience in the agricultural sector as central to national food security and poverty reduction goals (GGCRS, 2022; MINAGRI, 2024).

The gendered dimensions of climate vulnerability and adaptation in agriculture are systematically addressed through Rwanda's strong policy commitment to gender equality, primarily articulated in the Revised National Gender Policy (2021). This policy mandates gender mainstreaming across all sectors and policies, including climate change, environment, agriculture, and disaster management. It explicitly recognizes that women smallholder farmers, often constrained by limited access to and control over productive resources (especially land), finance, information, and technology, face disproportionate burdens from climate impacts and may have different adaptation capacities and needs than men. Consequently, the Gender Policy (2021) requires that climate adaptation strategies, including those promoted under the GGCRS (2022) and NECCP (2021) in the agricultural sector, are designed and implemented to be gender responsive. This involves ensuring women's equal participation in decision-making on adaptation planning, equitable access to climate-resilient inputs, training, and technologies, and addressing their specific vulnerabilities through targeted support mechanisms. The National Land Policy (2019) further supports this by strengthening women's land rights (e.g., through co-titling), which is foundational for their long-term investment in sustainable and climate-resilient farming practices and access to credit for adaptation (MIGEPROF, 2021; MoE, 2019).

Complementing these frameworks, the National Disaster Risk Reduction and Management Policy (2023) directly addresses the increasing climate-related disaster risks impacting agriculture and rural communities. It emphasizes proactive, community-based disaster risk management, early warning systems, and preparedness all crucial for safeguarding agricultural assets and livelihoods from climate shocks like floods and landslides. Critically, this policy also underscores the need for gender-sensitive disaster risk reduction (UNDRR) approaches, ensuring women's specific needs and roles in early warning dissemination, community response, and recovery are integrated, aligning with the mandates of the Gender Policy (2021). Collectively, these policies demonstrate Rwanda's clear development orientation: building a climate-resilient agricultural sector and safeguarding rural livelihoods requires deliberate, cross-cutting strategies that mainstream gender equality. Success hinges on implementing gender-responsive CSA, enhancing women's access to and control over resources (land, finance, technology, information), strengthening their participation in adaptation planning, and ensuring DRR measures protect their specific needs, thereby enabling equitable and sustainable adaptation for all smallholder farmers as envisioned in

NST2 (2024-2029) and Vision 2050 (GoR, 2020b; MIGEPROF, 2021; Republic of Rwanda, 2024).

2.4.2. Existing Policy Frameworks

Rwanda has made substantial efforts in addressing climate change and mainstreaming gender equality in its development and environmental frameworks. These efforts are especially relevant for smallholder farmers, who make up over 70% of the country's agricultural workforce and are particularly vulnerable to climate change impacts.

- **Green Growth and Climate Resilience Strategy (GGCRS)**

The Green Growth and Climate Resilience Strategy (GGCRS) 2022 emphasizes the need to integrate climate resilience into agricultural production and rural livelihoods, particularly concerning the impacts of climate change. As Rwanda aims to achieve a climate-resilient and low-carbon economy by 2050, the strategy recognizes that smallholder farmers are disproportionately affected by climate-related challenges such as droughts, floods, and soil degradation. The GGCRS advocates for sustainable agricultural practices, including the promotion of climate-resilient seeds and the adoption of agro ecological methods. It underscores the importance of ensuring food security while enhancing farmers' adaptive capacities to mitigate climate risks, thereby contributing to sustainable rural development and preserving natural resources (GGCRS, 2022).

In addressing the gendered dimensions of adaptation strategies, the GGCRS highlights that women often play a critical role in agricultural production and food systems but face unique challenges in the context of climate change. The strategy promotes inclusive growth that prioritizes women's access to resources, training, and decision-making processes. By ensuring that women farmers are equipped with skills and resources to adopt new agricultural technologies and practices, the GGCRS seeks to enhance their resilience against climate-induced impacts. Programs aimed at supporting women's empowerment in agriculture are integral to building a more resilient rural economy, aligning with the overarching goals of the strategy to develop an inclusive and sustainable agricultural sector (GGCRS, 2022).

Moreover, the GGCRS outlines several thematic program areas that focus on enhancing rural livelihoods through green industrialization and sustainable land use management. These programs encourage the diversification of livelihoods among smallholder farmers, promoting alternative income-generating activities alongside traditional agriculture. By integrating climate-smart agricultural practices and supporting rural infrastructure development, the strategy aims to improve the overall quality of life for rural populations, particularly for marginalized groups such as women. This comprehensive approach not only addresses the immediate impacts of climate change on agricultural production but also empowers communities to adapt and thrive in the face of future environmental challenges (GGCRS, 2022).

- **National Disaster Risk Reduction and Management Policy (2023)**

The National Disaster Risk Reduction and Management (DRRM) Policy in Rwanda emphasizes the importance of understanding disaster risks, particularly in the context of climate change and its impacts on agricultural production and rural livelihoods (MINEMA, 2018). The increasing frequency and intensity of climate-related disasters, such as droughts and floods, significantly affect the agricultural sector, which is vital for the livelihoods of many Rwandans. Smallholder farmers, who form the backbone of the agricultural system, are particularly vulnerable to these climatic changes. The policy highlights the necessity of comprehensive risk assessments and the integration of climate risk management into agricultural planning to enhance resilience among these farmers, thereby safeguarding food security and promoting sustainable rural livelihoods.

Furthermore, the policy framework recognizes that gender dynamics play a crucial role in adaptation strategies related to climate change impacts. Women, often responsible for food production and household management, face specific challenges that can limit their adaptive capacities. The DRRM policy aims to promote gender-sensitive approaches in agricultural practices and disaster management by identifying barriers that prevent women from effectively adapting to climate change. Initiatives such as providing training and resources tailored to women’s needs, as well as encouraging gender-inclusive decision-making in community planning, are central to the policy’s gendered adaptation strategies.

To effectively implement these strategies, the DRRM policy delineates specific actions that promote collaboration among stakeholders, including government institutions, communities, and non-governmental organizations (NGOs). These actions include enhancing community-based disaster risk reduction initiatives, promoting sustainable land use, and integrating adaptive agricultural techniques that are resilient to climate variability. By establishing clear roles and responsibilities, the policy seeks to foster a coordinated response that supports smallholder farmers in both mitigating risks associated with climate change and enhancing their livelihoods through sustainable agricultural practices (MINEMA, 2018).

- **National Adaptation Plan (NAP)**

Rwanda's NAP outlines priority areas for adaptation, with agriculture, water, and land use among the key sectors. It includes gender considerations as a cross-cutting issue, recognizing that women farmers often have less access to resources, yet are crucial actors in climate resilience. "Strengthening gender-responsive climate services and technologies is vital to support female smallholder farmers." (MIGEPROF, 2020)

- **National Land Use and Development Master Plan (2020-2050)**

The National Land Use and Development Master Plan (NLUDMP) for 2020-2050 addresses the intricate relationship between climate change and agricultural production in Rwanda, emphasizing the need for sustainable agricultural practices to ensure food security and resilience among smallholder farmers (MoE, 2020). As Rwanda anticipates a rise in climate variability, the plan highlights projections that suggest a temperature increase of 1.4°C to 2.3°C and a potential annual rainfall increase of 5% to 10% by the 2050s (MoE, 2020). Such climatic changes pose significant risks to agricultural productivity, given that the livelihoods of a large portion of the rural population is heavily reliant on agriculture. The NLUDMP outlines various strategies to mitigate these impacts, including the mainstreaming of climate change considerations into all development plans and the enhancement of adaptive capacities within agricultural systems.

The NLUDMP specifically recognizes that rural livelihoods, particularly for women and marginalized groups, will face heightened vulnerabilities due to climate change. Women's roles in agriculture are often crucial yet undervalued, and climate impacts can exacerbate existing gender inequalities in access to resources, decision-making, and adaptive capacity (MoE, 2020). To address these disparities, the NLUDMP suggests that gender-sensitive adaptation strategies should be integrated into agricultural planning. This could include training programs to improve women’s skills in climate-resilient agricultural practices, access to credit for sustainable technologies, and creating platforms that empower women to participate in decision-making processes related to land use and agriculture.

Furthermore, by advocating for the consolidation of agricultural land and improved land management, the NLUDMP aims to increase yields through economies of scale while reducing land fragmentation. Such an approach not only enhances productivity but also promotes community cooperation, vital for fostering resilience among smallholder farmers (MoE, 2020). Additionally, the incorporation of innovative practices, such as climate-smart agriculture and agroforestry, can further help mitigate the adverse effects of climate change, ensuring that smallholder farmers, particularly women, can adapt and thrive in a changing environment. Overall, the NLUDMP provides a robust framework for aligning climate action with agricultural development while considering gendered implications, thus fostering sustainable rural livelihoods in Rwanda.

- **Strategic Plan for Agriculture Transformation (PSTA 4) (2024-2029)**

The Strategic Plan for Agriculture Transformation (PSTA 4) for the period 2024-2029 is designed as a crucial component of Rwanda’s National Strategy for Transformation (NST2), which aligns with the broader Vision 2050 objectives. This framework seeks to enhance the agricultural sector by increasing productivity, ensuring food security, and promoting sustainable agricultural practices. It aims to transition agriculture into a more modern and climate-resilient sector. Key goals include achieving an annual agricultural growth rate of over 6% and significantly improving the efficiency of agricultural practices through the adoption of climate-resilient technologies and skilled labour. Specific interventions will involve optimizing land use, expanding irrigation systems, and implementing modern inputs such as fertilizers and improved seeds (MINAGRI, 2024).

The PSTA 4 strategy will prioritize the development of robust agricultural value chains and market linkages to enhance the competitiveness of Rwandan agricultural products in both local and international markets. This includes scaling up investments in key agricultural subsectors, including livestock and aquaculture, while focusing on modern farming practices such as zero grazing and improved animal genetics. Initiatives for improving post-harvest management and reducing losses will also be critical for enhancing food security and increasing farmer incomes. Additionally, the strategy emphasizes collaboration among various stakeholders government institutions, private sector actors, and farmers to facilitate innovation and resource mobilization, thereby strengthening the agricultural ecosystem (GoR, 2020a; MINAGRI, 2024).

Furthermore, PSTA 4 will address the pressing issue of youth unemployment by creating opportunities for young people in agriculture through training, education, and access to financing. The framework will strengthen public-private partnerships to ensure that investments lead to sustainable and decent job creation within the agricultural sector. By aligning with the NST2's objectives of promoting sustainable economic development and addressing challenges such as high youth unemployment and trade deficits, the PSTA 4 framework aims not only to modernize agriculture but also to improve the quality of life for all Rwandans and ensure that agriculture serves as a foundation for broader economic growth (GoR, 2020a; MINAGRI, 2024).

- **National Environment and Climate Change Policy**

Rwanda's National Environment and Climate Change Policy emphasizes the need for climate resilience within the agricultural sector, recognizing that climate variability poses significant challenges to agricultural production and rural livelihoods. This policy frames the issues of climate change effects on agriculture by addressing essential factors such as land degradation, water scarcity, and increased frequency of extreme weather events. Smallholder farmers, who constitute a crucial part of Rwanda's agricultural landscape, are particularly vulnerable to these climate impacts. The policy acknowledges that women and marginalized groups face additional challenges due to gender disparities in access to resources and decision-making processes in agriculture (Republic of Rwanda, 2020).

In response to the challenges outlined above, the National Environment and Climate Change Policy sets forth specific objectives aimed at enhancing the adaptive capacity of smallholder farmers. These include promoting climate-smart agricultural practices, which integrate climate information into decision-making processes. This is crucial for smallholder farmers to better assess risks and implement adaptive strategies. The policy also promotes inclusivity and participation by ensuring that various stakeholders, including women and youth, are involved in climate change discussions and interventions tailored to their unique needs. This participatory approach helps in identifying gendered adaptation strategies that can effectively address the distinct roles and responsibilities of different community members (Republic of Rwanda, 2020).

Furthermore, the policy encourages the use of innovative technologies and sustainable practices such as agro ecological methods that can improve rural livelihoods while reducing vulnerability to climate change. Initiatives aimed at strengthening institutional coordination and promoting access to climate finance are essential for supporting smallholder farmers in implementing these strategies. By linking agricultural practices to sustainable environmental management, the policy not only seeks to improve agricultural productivity but also aims to ensure that rural communities, particularly women smallholder farmers, can thrive despite the ongoing challenges posed by climate variability and change (Republic of Rwanda, 2020).

- **Gender and Climate Change Strategy**

The Revised National Gender Policy of Rwanda emphasizes the critical intersection between gender equality and climate change, particularly regarding agricultural production and rural livelihoods (MIGEPROF, 2021). The effects of climate change, such as soil erosion, destructive rains, and diminishing soil fertility, pose significant risks to agricultural outputs, which are a primary source of income for many smallholder farmers. The government recognizes that both men and women are affected by these challenges but that the impacts are often disproportionately felt by women due to existing socioeconomic inequalities and the traditional division of labour within households (MIGEPROF, 2021). Therefore, enhancing adaptive capacities to climate change requires specific attention to the gendered experiences and roles of farmers in rural environments.

To address these challenges, the policy outlines targeted strategies focused on increasing women's participation in agricultural practices and decision-making processes. This includes promoting women's access to agricultural extension services and technologies that can help them adapt their farming practices to changing climate conditions (MIGEPROF, 2021). For instance, increasing women's participation in proximity agricultural extension services can lead to greater comfort and enthusiasm among female farmers in engaging with new agricultural programs. By mobilizing and building women's capacities to engage in more productive agricultural value chains such as agro-processing and irrigation these initiatives aim to enhance their economic empowerment and resilience against climate variability.

Furthermore, the strategy advocates for a collaborative approach among various stakeholders, integrating gender considerations into climate change responses. This includes establishing mechanisms that empower women to benefit from agriculture-related insurance programs and cross-border trade opportunities promoted through regional economic groupings. The overarching goal is to ensure that both men and women can effectively utilize available resources while promoting equitable access to finance and technical support in agriculture. By aligning these efforts with the Sustainable Development Goals and the African Union Agenda 2063, Rwanda seeks to position itself as a leader in gender-responsive climate change adaptation strategies, fostering sustainable development that considers gender equity and empowers rural livelihoods across the nation (MIGEPROF, 2021).

2.5. Existing Gender Adaptation Strategies to Reduce Impacts of Climate Change on Smallholder Farmers

2.5.1. Introduction of Gender Adaptation Strategies to Reduce Impacts of Climate Change on Smallholder Formers

CSA is an approach to developing the technical, policy, and investment conditions the enabling environment to support actions aimed at achieving sustainable agricultural development for food and nutrition security under a changing climate. CSA aims to sustainably improve agricultural productivity and enhance food security, increase farmers' resilience and adaptation to climate change, and reduce and/or remove greenhouse gas (GHG) emissions where possible (Bruinsma, 2017). FAO launched the term CSA in the background document prepared for the 2010 Hague Conference on Food Security, Agriculture, and Climate Change.

However, Gender-responsive policy and practice recognize and address the specific needs and realities of women and men based on the social construction of gender roles. Gender transformative interventions seek to transform gender roles and promote more gender-equitable relationships between men and women. They challenge the underlying causes of gender inequality that is rooted in broad political, economic, and sociocultural structures. Because gender-transformative approaches seek to change rigid gender roles and relations, such approaches often go beyond the individual level to focus on interpersonal, social, structural, and institutional practices to address gender inequalities (Morgan, 2014). Gender as it pertains to many sectors health, education, agriculture and many domains within agriculture (from crop and livestock production to natural resource management and agro-processing) is also pertinent to CSA, but only recently have gender and CSA been researched together to provide more empirical guidance for deciding how they should be considered together in designing projects, programs, and policies. These studies suggest that more female as well as male farmers adopt climate smart technologies and practices in agriculture when women's awareness, knowledge, and access to information about such practices increases with the ultimate effect of strengthening the resilience of households, communities, and food systems exposed to climate-related shocks and climate change.

Even more fundamentally, these studies suggest that a host of other factors can influence female producers' adoption of climate-smart approaches, including legal or sociocultural constraints on women's accumulation and control of assets and resources, constraints on women's mobility, as well as the likely effects of climate smart practices on women's time and labour commitments or share of the benefits. Beuchelt and Badstue (2013) present a helpful framework for thinking about opportunities and trade-offs in interventions, policies, and actions aimed at enhancing gen der and social equity in CSA (figure 1). The inner part of the circle shows key considerations that include livelihood planting date or changes in crop varieties), yet practices leading to more transformative change (such as diversified livelihoods and an increase in assets) are needed if agriculture is to withstand the effects of climate change while bringing about improved productivity and food and nutrition security, increased economic growth, shared prosperity, and the ultimate goal of growth with social equality.

Producers will require enhanced targeted incentives, improved agricultural services, more efficient input and output markets, and policy changes. Policy changes are particularly critical for effective, sustainable, and inclusive CSA. For example, securing women's right to own land (and thus protect their investments in CSA) may require efforts to address customary and civil law regarding property rights; in areas where the definition of a household excludes women from participation in farmer groups, women's inclusion in CSA initiatives will be restricted. Figure 1: Conceptual Framework for Enhancing Gender and Social Equity in nutrition- and Climate-Smart agriculture

According Asfaw (2015), the examples of climate-smart agricultural practices come from case studies in East Africa, West Africa, and South Asia. Note that the practices are context specific in other words, they will be applied differently in different environments. A practice may be climate smart in one context but not in another, depending on how, where, and why it is used. Practices also have different social dimensions depending on the area and culture in which they are implemented.

2.5.2. Improved Land and Water Management Practices

- Agroforestry, in which trees are planted together with crops on the farm, generally makes use of trees that produce or are primarily used for fruit, fodder, or fuel wood. Aside from these benefits, the trees can reduce runoff or erosion, enhance soil fertility, and provide shade functions that are important for adapting to climate change in addition to sequestering carbon, which has benefits for mitigating the effects of climate change.

- Terraces and bunds are physical structures placed along contours to slow the runoff of water and enhance its absorption. They can be an important measure for adapting to water scarcity arising from climate change.

- Water harvesting structures and systems are another important adaptation measure with food and nutrition security impacts collect water from a surface area for irrigation or for improved filtration. These systems can be small or large, ranging from individual farms and plots to a much more considerable area. Structures can include water ditches and water pans, which must be managed well to control mosquitos and malaria.

- Improved agricultural water management includes small-scale irrigation and improved management of water from ground and surface sources.

- Planting pits are pits of different sizes used for planting and to help conserve water.

- Crop residue mulching involves leaving crop material on the field after the harvest to improve soil texture, prevent erosion, and encourage water filtration.

2.5.3. Improved Soil Fertility and Crop Management Practices

- Composting involves removing crop residues to allow them to decompose and then adding them back to the soil to improve soil fertility and texture and allow for improved water filtration.

- Cover cropping ensures that fields are covered by vegetation that protects soil from eroding between crop production cycles. Some cover crops also enhance soil fertility or suppress pests.

- Conservation agriculture involves maintaining a permanent organic soil cover from cover crops, inter crops, or residues/mulch, minimizing soil disturbance through tillage, and diversifying crop rotations (for example, with legumes).

- Efficient use of fertilizer means that producers optimize the amounts and types of fertilizer (synthetic and organic) they use. Examples of efficient fertilizer practices include using a mix of fertilizer components that reflects actual soil and crop needs; deep placement of fertilizer; microdosing; and changing from one fertilizer application at the beginning of the crop cycle to three (smaller) fertilizer applications throughout the crop cycle.

- Improved, high-yielding varieties are grain, legume, fruit, and vegetable varieties that have been bred to improve and increase yields and that are purchased and used in conjunction with other CSA practices.

- Stress-tolerant varieties are bred specifically to be adapted to climate challenges in a particular region, such as droughts, floods and submergence, saline or acidic soils, and pests.

- No-till or minimum tillage practices involve opening the soil only where the seeds are placed, with as little soil disturbance as possible; it is a component of conservation agriculture.
- Alternate wetting and drying for rice management involves improved water management and reduces GHG emissions.

2.5.4. Improved Livestock Management Practices

- Improved feed management entails storing animal feeds (Stover, grass, grain) and making better use of feed (by combining types of feed), growing grass varieties specifically suited to the agro-ecological zone, and many other practices, such as fodder conservation and animal fattening.
- Livestock manure management is the collection and storage of livestock manure for future application to producers' fields.
- Destocking is a planned effort to reduce the number of livestock and manage the herd more efficiently (by selling animals if drought is projected, for example), as opposed to sudden distress sales provoked by hard ship. It improves resilience and reduces GHG emissions.
- Switching to livestock species or breeds that are more adapted to water scarcity and resistant to disease can include buying or breeding such animals or even changing the type or species of animal produced. For example, Zebu cattle and small ruminants are more tolerant of water scarcity.
- Pasture management, which includes rotational grazing and setting paddocks aside in case of drought, improves risk management and reduces GHG emissions

Chapter 3. Methodology

The methodology including study area description, data collection method and techniques including primary and secondary data collection.

3.1. Study Area Description

Bahimba wetland is located in Rulindo District as one of the five Districts that make up the Northern Province. Rulindo District is bordered by Nyarugenge and Gasabo Districts in the south, Gicumbi District in the east, Gakenke District in the west and Burera District in the north. Rulindo district has 17 administrative Sectors, with 71 Cells and 494 Villages (Imidugudu) and cover a surface area of approximately 567 km2. The population of Rulindo District is 360,144, where 171,849 are males and 188,295 are females (NISR, 2022b). Rulindo has significant water reservoirs from local sources including rivers that have a steady flow into valleys that enables the district to have water even during the dry seasons. The main rivers that flow into the district are Base, Bahimba, Mulindi, Cyonyonyo, Cyohoha, and Rukeri Muyanza. The topography of Rulindo district contributes to flooding, landslides and erosion. For instance, this area is characterized by many hills among which include Tare, Tumba and Cyungo hills with their altitude rising to 2,438 m. These hills are interspersed by valleys and swamps that border rivers. The interweaving of hills and valleys with rivers provides a beautiful and eye catching scenery to both citizens and visitors (IUCN, 2022).

District has a tropical climate, characterized by a succession of rainy seasons and droughts. The dry season usually extends from January to February, and June to August. The rainy season normally stretches from March to May and from September to December. The average annual temperature is 19°C. High temperatures are observed in August where they reach 28°C in the middle of the day. During the rainy seasons, the district encounters concentrations of mists in the valleys in the mornings and on the hilltops in the late morning. Rainfall normally reaches 1,243 mm per year on average (Meteo-Rwanda). Soil erosion and soil nutrient loss are major problems in Rulindo District since most part of the district is hilly. The erosion takes what would be the fertile soil to rivers and wetlands. Shyorongi Sector is the worst affected with an area estimated to 800 ha (22% of the land) at risk of erosion, followed by Rukozo Sector with 235 ha (17%), and

Rusiga Sector with 466 hectares (16% of sector land at risk). The presence of gullies in Shyorongi, Rukozo, Rusiga, Cyinzuzi and Tumba Sectors confirms the findings of the CROM model. Erosion control measures have been taken and therefore runoffs have been reduced through agroforestry, and radical and progressive terraces (Rulindo, 2023).

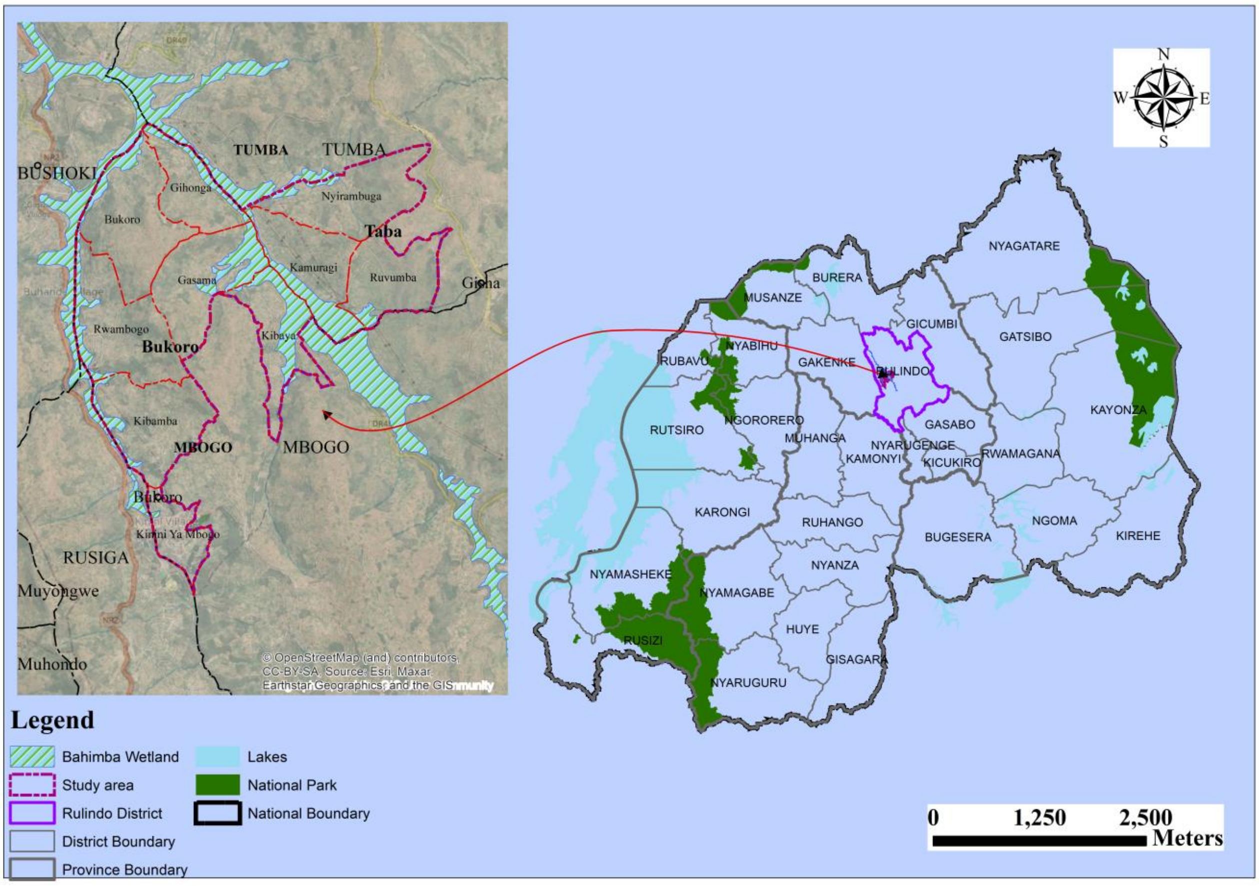

Figure 1: **Map of Bahimba Wetland in Rulindo District**

Source: (NLA, 2025)

As shown in Table 1 above, the collection of primary data focused on two sectors, two cells, and ten (10) villages neighbouring Bahimba wetland. These specific administrative entities were selected due to their high vulnerability to climate change effects compared to other sectors surrounding the wetland. In fact, elevation combined with changing rainfall patterns makes the region more vulnerable to climate-induced disasters such as flooding and soil erosion particularly during the rainy seasons from September to December and from March to May.

These different types of climate-related disasters disproportionately affect smallholder farmers, especially women, who are more dependent on wetlands for agriculture, food production, and household water use. Women often have limited access to climate-resilient technologies, land ownership, and decision-making power, making them more exposed to risk. The selection of Bahimba wetland as a study site, furthermore, provides a critical opportunity to examine how gender influences adaptation strategies and the differential effects of climate change. It enables a deeper understanding of how climate-related challenges intersect with gender roles and responsibilities within smallholder farming communities.

Table 1: **Selected Sites for Field Survey (Sectors, Cells and Villages)**

Name of Sector	Name of Cell	Name of Village
Mbogo	Bukoro	Kinini ya Mbogo
		Kibamba
		Rwambogo
		Bukoro
		Gihonga
		Gasama
		Kibaya
Tumba	Taba	Ruvumba
		Kamuragi
		Nyirambuga

3.2. Data Collection Methods and Techniques

I employed both primary and secondary data collection such as interview, questionnaire, filed observation and literature review for collecting information about major indicators of climate change and their adverse effects on agricultural production in the study area, the extent to which smallholder farmers are vulnerable to climate change effects with a focus on gender dimension and gendered approaches adaptation strategies to reduce impacts of climatic change.

3.2.1. Secondary Data Collection

The literature review focused on extracting information about the major indicators of climate change, the result of gender characters, and the adaptation approaches engaged by male and female smallholder farmers. Particular attentions were given to how gender shapes vulnerability, access to resources, decision-making power, and adaptive capacity in the perspective of climatic changes. The review was made through reports from local leaders at the sector, district, and national levels. It was also include books, peer-reviewed journals, articles, and official reports from international bodies such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC); scientific and technical publications from UN agencies such as the World Meteorological Organization (WMO), Food and Agriculture Organization (FAO), and United Nations Environment Programme (UNEP); and national policy documents and strategies from Government of Rwanda institutions, including the Ministry of Disaster Management and Refugee Affairs (MIDIMAR), Ministry of Agriculture (MINAGRI), National Institute of Statistics (NISR), Rwanda Meteorological Agency, and Rwanda Environment Management Authority (REMA). Special highlighting will be placed on documents and data that highlight gender dynamics in climate adaptation.

3.2.2. Primary Data Collection

Primary data collection I was employed the following consisting method including field observation, interview and questionnaire

3.2.2.1 Field Observations

The field observations were focused on considering the biophysical status of wetlands and the surrounding landscape to gain a comprehensive understanding of the current situation. The primary objective is to evaluate the extent of soil erosion and flooding affecting wetlands, particularly in relation to climate change impacts. During the field visit, we were analysing various factors contributing to land degradation, including smallholder farmers' exposure to erosion risks, causes of soil erosion in wetlands, factors influencing landslides, and climatic impacts on smallholder farming systems. A gender lens was applied throughout the observation process to identify how men and women smallholder farmers experience and respond differently to these environmental stressors. This includes examining gender-specific vulnerabilities, access to resources, and participation in land management practices. The insights gathered will inform the development of equitable and gender-sensitive mitigation strategies to address climate change-related challenges in wetland ecosystems.

3.2.2.2 Household Questionnaire Survey

A randomly selected sample of 95 households from Bukoro Cell in Mbogo Sector and Taba Cell in Tumba Sector will complete a semi-structured questionnaire. The survey was emphasized evaluating the exposure, sensitivity, and adaptive capacity of different gender groups specifically men and women in wetland areas in reaction to climate change and variability. The study intends to catch the different ways in which men and women experience and react to climate-related challenges by breaking down data by gender. This strategy was draw attention to gender-specific vulnerabilities, duties, and coping mechanisms, therefore helping to a complex knowledge of resilience patterns and guiding more fair and inclusive adaptation efforts.

a) Sampling Methods

(i) Targeted Population

The targeted population is estimated at 2,057 households (HHs). This estimation was based on the number of HHs living in the identified soil erosion and landslide hotspots within nominated villages and cells. Due to the absence of disaggregated data by cells and villages in the 2022 Population and Housing Census, I relied on a local government report that provided household statistics for the study area. In addition, a gender-sensitive approach will be applied throughout the research, recognizing that men and women may face different exposures, roles, and coping strategies in relation to landslide risks. Therefore, the household data will be further examined to capture gender dynamics, ensuring that both male- and female-headed households are adequately represented in the analysis.

Table 2: **Targeted Population for Quantitative Household Survey**

Name of Sector	Name of Cell	Name of Village	Targeted Population=Number of HHs in Selected Villages
Mbogo	Bukoro	Kinini ya Mbogo	325
		Kibamba	130
		Rwambogo	140
		Bukoro	320
		Gihonga	210
		Gasama	230
		Kibaya	118
Tumba	Taba	Ruvumba	238
		Kamuragi	194
		Nyirambuga	152
Total			**2,057**

Source: Author's Analysis (2025).

(ii) Sample Size Determination

The data collection for this study was conducted through quantitative household surveys across two sectors, two cells, and ten (10) villages in Rulindo District. These locations were purposefully selected due to their heightened vulnerability to the effects of climate change, particularly among smallholder farmers residing around the Bahimba wetland. The area's hilly topography, high elevation, and exposure to extreme weather events such as flooding and soil erosion during rainy seasons make it a critical zone for assessing climate change impacts on livelihoods.

The total target population comprised approximately 2,057 households (HHs) residing in the identified hotspots. Due to the absence of disaggregated census data at the village level, local administrative records were used to estimate the household population for each village.

Using Sugiyono (2013), the required sample size is determined using the following formula:

$$S = \frac{N.\ P.\ Q.\ \lambda^2}{d^2(N-1) + P.\ Q.\ \lambda^2}$$

Where: λ^2 = Error standard = 1 d = Standard deviation = 0.05

P = Q = Probability = 0.5   S = Total sample
N = Population

To ensure representativeness, a purposive sampling technique was employed. This method enables proportional allocation of the 95 households through the two cells and ten villages, based on the number of households in each village. The number of households selected per village was computed by multiplying the proportion of HHs in each village by the total sample size. This approach ensured equitable representation of communities, particularly those at higher risk of climate-related challenges. Moreover, within each stratum, efforts were made to capture gender diversity by ensuring that both male- and female-headed households are included in the sample. This facilitated a gender-sensitive analysis of how climate-related risks and adaptation strategies change across different household types. Fifty-eight percent of the selected households were headed by women, while the remaining 37 percent were headed by men, in line with the aim of applying a gender-based perspective.

Table 3: **Sample Size for Quantitative Household Questionnaire**

Sector	**Cell**	**Village**	**Targeted Population=Number of HHs in Selected Villages**	**%**	**Sample Size**	**Sample Size of HH Headed by Women**	**Sample Size of HH Headed by Men**
Mbogo	Bukoro	Kinini ya Mbogo	325	16	16/100*95=15	60*15/100=9	6
		Kibamba	130	6	6/100*95=6	60*6/100=4	2
		Rwambogo	140	7	7/100*95=7	60*7/100=4	3
		Bukoro	320	16	16/100*95=15	60*15/100=9	6
		Gihonga	210	10	10/10*95=10	60*10/100=6	4
		Gasama	230	11	11/100*95=10	60*10/100=6	4
		Kibaya	118	6	6/100*95=6	60*6/100=4	2
Tumba	Taba	Ruvumba	238	12	12/100*95=11	60*11/100=7	4
		Kamuragi	194	9	9/100*95=8	60*8/100=5	3
		Nyirambuga	152	7	7/100*95=7	60*7/100=4	3
Total			**2057**	**100**	**95**	**58**	**37**

Source: Author's Analysis (2025).

(iii) Questionnaire Administration

Data collection was conducted by me using a household questionnaire. I prepared the questionnaire survey in advance. However, Data were collected through structured, face-to-face household interviews using a standardized questionnaire. Key respondents included the Executive Secretaries of Cells, SEDOs of Cells, Heads of Villages, and Heads of Cooperatives of smallholder farmers. The questionnaire was designed to gather data on several themes: the socio-economic and demographic characteristics of the household; agricultural practices and observed changes linked to climate variability; the effects of climate change on rural livelihoods and household welfare; adaptation strategies adopted at both the household and community levels; and gender-specific roles, challenges, and coping mechanisms in response to climate change.

3.2.2.3. Interviews

Purposive interviews were used as the primary data collection method. The main respondents included local leaders, stakeholders, and leaders of the COVAMA c

ooperative who coordinate farming activities in the Bahimba wetland. Key informants comprised two Sector Agronomist Officers, SEDOs, Executive Secretaries of cells, village leaders, women's platform representatives from the sector to village level, and para-social workers around the Bahimba wetland. Emphasis was placed on including both male and female voices to capture gender-differentiated perspectives on the impacts of climate change. This approach helped uncover how gender roles, responsibilities, and access to resources influenced smallholder farmers' perceptions of and adaptation strategies to climate change. The interviews explored how women's and men's experiences differed in relation to climate variability, agricultural productivity, and decision-making processes in rural communities neighbouring the Bahimba wetland. All interviews were recorded using sound devices and documented for analysis.

Table 4: **Selected Professionals and Decision-makers for Interview**

Population to be interview	Total Population	Sample size
Cells Executives (4 cells)	2	2
Cells Social Economic development Officers (SEDOs)	2	2
Sector Agronomist	2	2
Sector Social Affairs	2	2
District Agronomist	1	1
Total	**9**	**9**

Source: Author's Analysis (2025).

3.3. Data Analysis and Interpretation

3.3.1. Descriptive Statistics

Descriptive statistical analysis was employed to summarize and interpret the fundamental characteristics of the data in this study. This approach facilitated the presentation of concise yet insightful summaries of the sample and its associated measures. Given that research studies often produce extensive datasets encompassing multiple variables and numerous respondents, the application of descriptive statistics was essential for systematically organizing and simplifying complex data. By reducing large datasets into comprehensible summaries, descriptive statistics enhanced the clarity and interpretability of the findings. In this study, descriptive statistical analysis was utilized to assess key respondent attributes, including age, income, household size, gender, marital status, educational attainment, occupation, perceived impacts of climate change, and existing adaptation strategies. Descriptive statistics were also used to illustrate the frequency of respondents according to categories such as age, occupation, income, and other demographic characteristics.

In addition, the Chi-Square test was used to examine the level of association between variables. Specifically, two types of variables—independent and dependent—were analyzed. The test assessed the significance of relationships between respondents' characteristics and gendered impacts of climate change, as well as their current adaptation strategies. The acceptance or rejection of the hypothesis was based on the value of the significance probability (p-value) in relation to the significance level ($\alpha = 0.05$). If the p-value was greater than α (0.05), the null hypothesis was accepted; if the p-value was less than or equal to α (0.05), the null hypothesis was rejected.

3.3.2. Use of Geospatial Technology and Applications

A. Soil erosion Analysis

This study intends to use geospatial technology specifically GIS and Remote Sensing to assess the impacts of climate change on smallholder farmers in the study area. For analyzing the effects of soil erosion, the study was employed the Revised Universal Soil Loss Equation (RUSLE) model, which utilized five key data components: climatic data, topographic contours, soil characteristics, crop data, and land management practices.

A gender-sensitive approach was integrated into the interpretation and application of these datasets. For example, differences in land use practices and crop management between male- and female-headed households will be considered when calculating the Cover Management Factor (C) and Support Practice Factor (P). Women smallholder farmers often face limited access to resources such as soil conservation technologies or land tenure security, which can influence the effectiveness of erosion control measures and should be reflected in spatial analysis. Similarly, the selection of crops—often gendered in many rural Rwandan community's affects ground cover and susceptibility to erosion and will be spatially analyzed to reveal differentiated risks.

The RUSLE model, expressed as $A = R \times K \times LS \times C \times P$, Ghosal and Das Bhattacharya (2020) where each factor reflects a component of the erosion process, will not only provide a scientific estimation of annual soil loss but were also allowed gender-based differentiation in vulnerability assessment. This approach will help identify areas where women or men are disproportionately affected by soil erosion, thus supporting the design of more equitable, targeted adaptation strategies.

B. Flooding

To assess the rate of flooding in the Bahimba wetland, Geographic Information System techniques were employed, specifically using spatial analysis tools such as weighted overlay. This method integrates multiple thematic layers to identify flood-prone areas based on the influence of selected environmental and hydrological factors. The key factors considered in this analysis were river density, drainage density, rainfall, elevation, land use/land cover (LULC), and slope. Each of these factors plays a critical role in determining the likelihood and extent of flooding. For instance, areas with high river and drainage densities or steep slopes may facilitate faster water movement, while certain land cover types, such as bare soil or urban surfaces, may increase runoff.

The process began by reclassifying each factor to standardize their influence on flooding risk, followed by resampling to ensure that all layers shared a common spatial resolution and scale for analysis. This step is essential for accurate overlay and comparison. After preprocessing, the layers were weighted according to their perceived contribution to flooding: rainfall was assigned the highest weight at 30%, followed by river density and slope at 20% each. Drainage density, LULC, and elevation were each given a weight of 10%. These weights were applied in the weighted overlay analysis to generate a composite flood risk map, which provided a spatial representation of flood-prone zones in the Bahimba wetland. This map serves as a valuable tool for flood risk management and informed land-use planning.

C. Landslide Analysis

I integrated GIS to analyse areas vulnerable to landslides in the Bahimba wetland. Six key factors were considered in the analysis: drainage density, distance from rivers, land use/land cover (LULC), slope, soil type, and rainfall. These factors were first reclassified using geospatial analysis tools to standardize their values. Resampling was applied to ensure all factors were on the same scale. A weighted overlay technique was then used to assign the following weights to each factor based on their influence: drainage density (15%), distance from rivers (20%), rainfall (30%), LULC (10%), slope (10%), and soil type (5%). This analysis produced a Landslide Susceptibility Index (Smith et al.) map, identifying areas most at risk of landslides.

D. Temperature and Precipitation Analysis

GIS was employed to analyse the spatial distribution of temperature and precipitation in the Bahimba Wetland. Rainfall and temperature data were obtained from Meteo-Rwanda. Spatial interpolation techniques, such as kriging, were used to assess the distribution patterns of these climatic variables. This analysis provided quantitative information on temperature and precipitation, which are critical factors affecting smallholder farmers in the Bahimba Wetland.

Chapter 4: Results and Discussion

The results in this section aim to address the research objectives outlined in the study. These objectives were formulated to describe major indicators of climate change and their adverse effects on agricultural production, assess the extent to which smallholder farmers are vulnerable to climate change effects and the impacts on rural livelihoods with a focus on gender dimension. And propose gendered approaches adaptation strategies to reduce impacts of climatic change on smallholder farmers in Bahimba Wetland.

4.1. Analysis of Socio-Demographic Aspects of Respondents

4.1.1. Age of Respondents

The age distribution of respondents shows that the majority (71.6%) fall between 31 and 65 years old, with 26.3% aged 31–45, 25.3% aged 46–55, and 20% aged 55–65. This indicates that the active farming population in Bahimba wetland largely consists of mature adults in their prime productive years. This demographic is particularly significant in understanding how climate change affects agricultural production and rural livelihoods since they often make key decisions on farm management, resource allocation, and adoption of adaptation strategies. Given their reliance on seasonal rainfall and wetlands cultivation, shifts in rainfall patterns and increased flooding threaten both food security and income stability for this age group, forcing them to adopt coping strategies such as crop diversification, soil conservation, and tree planting.

Meanwhile, the data also shows younger (18–30) and older (66+) respondents make up smaller proportions, 20% and 8.4% respectively. Younger farmers may be less experienced in traditional practices yet more open to adopting modern techniques, while the older cohort might rely on long-established methods and face limitations in physical labour, reducing their adaptive capacity. Gender also intersects with age: women, especially in older age groups, often have less access to resources like credit, land, and extension services, limiting their ability to adapt. Targeted gender-responsive policies and support for different age groups are thus critical for strengthening resilience and promoting sustainable livelihoods in Bahimba wetland amid climate change.

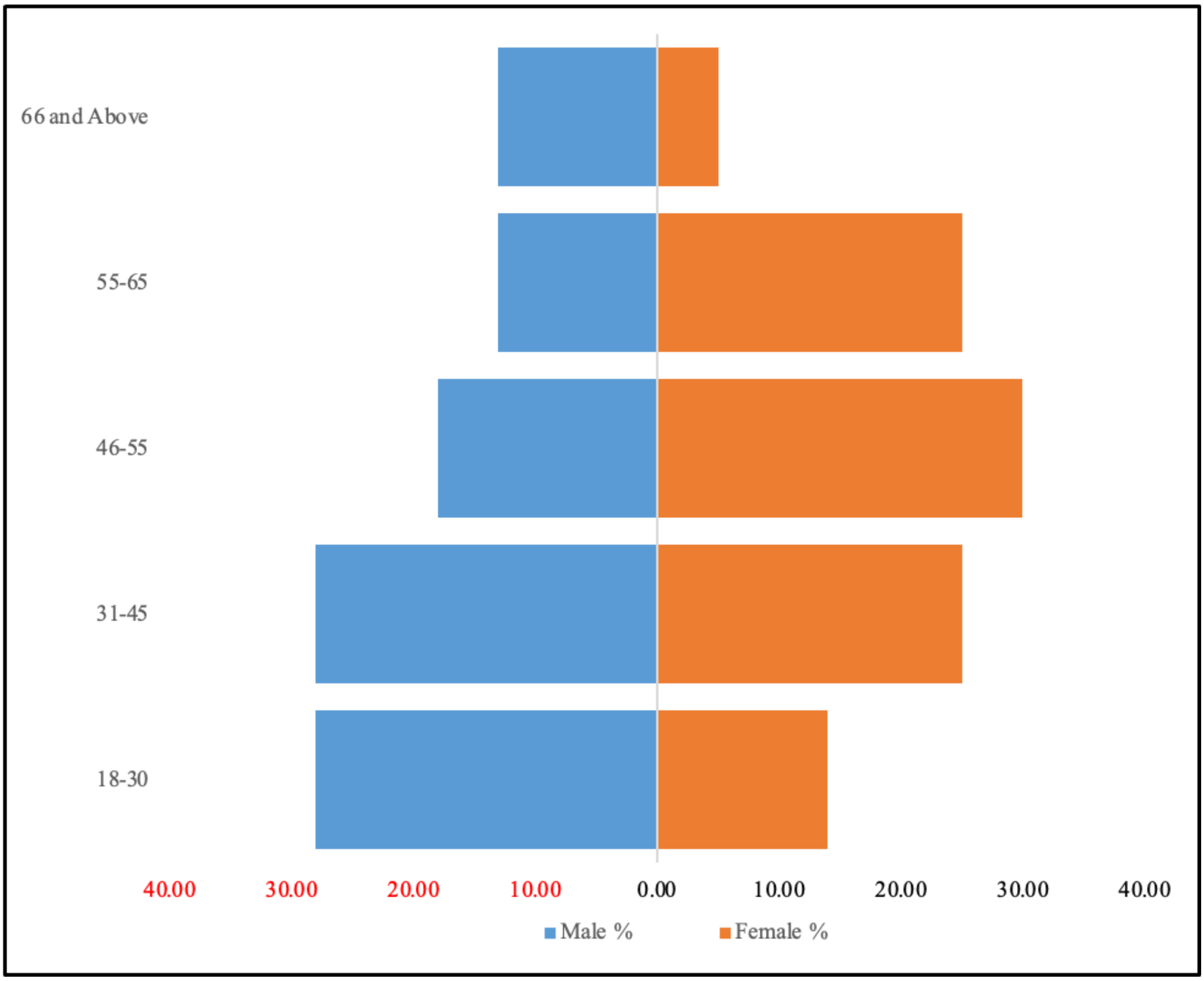

Figure 2: **Population Pyramid of Age of Respondents**

Source: Field data (2025).

4.1.2. Sex of Respondents

The gender distribution of respondents in Bahimba Wetland shows that 59% are female and 41% are male. This pattern underscores the significant role women play in agricultural production and rural livelihoods in this region. Women often carry the bulk of agricultural labour, particularly in wetlands where intensive manual work such as planting, weeding, and harvesting is crucial for household sustenance. Climate change exacerbates existing challenges faced by female farmers, including limited access to land ownership, credit, and agricultural extension services, which constrains their capacity to invest in adaptive measures like irrigation, improved seeds, or terracing to cope with increased rainfall variability and floods in wetland areas.

At the same time, this gender imbalance presents both an opportunity and a challenge for effective climate adaptation strategies. With women comprising the majority of respondents, integrating gender-sensitive approaches—such as improving women's access to climate information services, strengthening cooperatives, and supporting equitable participation in decision-making—can significantly boost community resilience. Policies and interventions in Bahimba Wetland must therefore prioritize women's empowerment and recognize their unique knowledge and contribution to farming systems, ensuring they are not disproportionately burdened by the impacts of climate change while also tapping into their potential as key agents of adaptation.

4.1.3. Family Size of Respondents

The distribution of family sizes among respondents in Bahimba Wetland reveals that the majority (61%) belong to households with 1–5 members, while 25% have 6–10 members, and only 14% are part of larger households with 11 or more members. Smaller family sizes may indicate limited household labour available for agricultural activities, which directly impacts the ability of smallholder farmers to implement labour-intensive adaptation strategies such as terracing, erosion control, or shifting to diversified crop systems in response to climate change. As wetlands become increasingly vulnerable to flooding and erratic rainfall, these small households may struggle to cope with agricultural disruptions without additional support mechanisms.

Conversely, larger households, although fewer in number, often have greater collective labor capacity, enabling them to experiment with new practices or manage larger areas of cultivation even under challenging conditions. However, these larger families also face increased pressure to produce sufficient food and income to meet basic needs, making them equally vulnerable when climate extremes disrupt agricultural output. Gender dynamics intersect with family size in this context: female-headed households, particularly those with smaller family sizes, may lack the necessary workforce and resources to adapt effectively. Thus, policies aimed at building resilience should consider household composition and gender roles, ensuring that adaptation support—such as labour-saving technologies, credit, and targeted extension services—reaches the most vulnerable family structures in Bahimba Wetland.

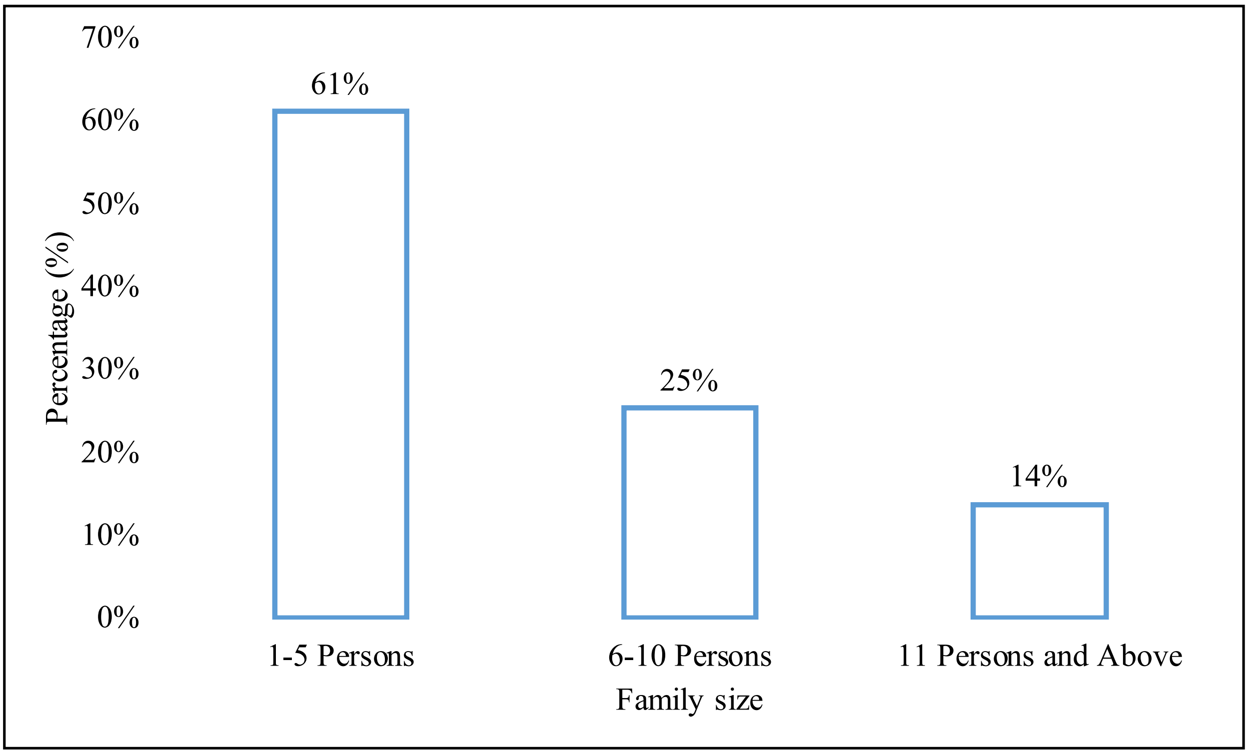

Figure 3: **Family Size among Respondents**

Source: Field data (2025).

4.1.4. Education of Respondents

The starkly limited education profile of respondents (38% no formal education, 24% incomplete primary, 18% complete primary – totalling 80% with only primary-level schooling or less) profoundly shapes their spatial relationship to the Bahimba Wetland and their capacity for climate adaptation. This low literacy and formal knowledge base strongly anchor agricultural practices and livelihood strategies to localized; experiential knowledge deeply embedded within the immediate physical environment of their landholdings. Farmers with minimal formal education are more likely to rely heavily on traditional, place-specific knowledge passed down intergenerational and honed through direct, long-term interaction with their specific plots – knowledge intrinsically tied to the wetland's hydrology, soil types, and microclimates. This creates a deep spatial dependence; their understanding of farming and adaptation is highly localized and less transferable. Consequently, they are potentially more vulnerable to spatially variable climate impacts (e.g., irregular flooding zones, localized drought pockets) if these changes exceed the scope of their inherited knowledge. Their ability to comprehend complex hydrological changes affecting different parts of the wetland or interpret regional climate forecasts is inherently constrained, limiting proactive spatial adaptation planning beyond their immediate vicinity.

This educational profile also critically influences access to information and new adaptation strategies, creating spatial gradients of vulnerability. The near absence of higher education (only 7% combined TVET/Secondary/University) suggests a severe lack of local "educated innovators" or individuals fluent in accessing and interpreting external scientific information or government extension services. Knowledge dissemination about new agricultural techniques, climate-resilient crops, or water management technologies likely relies heavily on verbal communication, local demonstrations, or radio methods whose reach diminishes with physical distance from community centers, extension offices, or main roads.

Households located in more remote, peripheral areas of the wetland catchment, potentially on less productive or more marginal land, are doubly disadvantaged: they face greater exposure to specific climate risks and have the least access to the formal information channels needed to adapt. Furthermore, given the documented gender gaps in education access in rural Rwanda, this overall low attainment likely masks an even more pronounced disadvantage for women farmers. Their potential spatial mobility to attend distant training sessions or access information hubs is often more restricted due to domestic responsibilities and social norms, amplifying their informational isolation and limiting their capacity to adopt spatially nuanced adaptation strategies, even within the same community or watershed. Their adaptation choices become even more tightly bound to the immediate, familiar spaces of their homesteads and nearby fields.

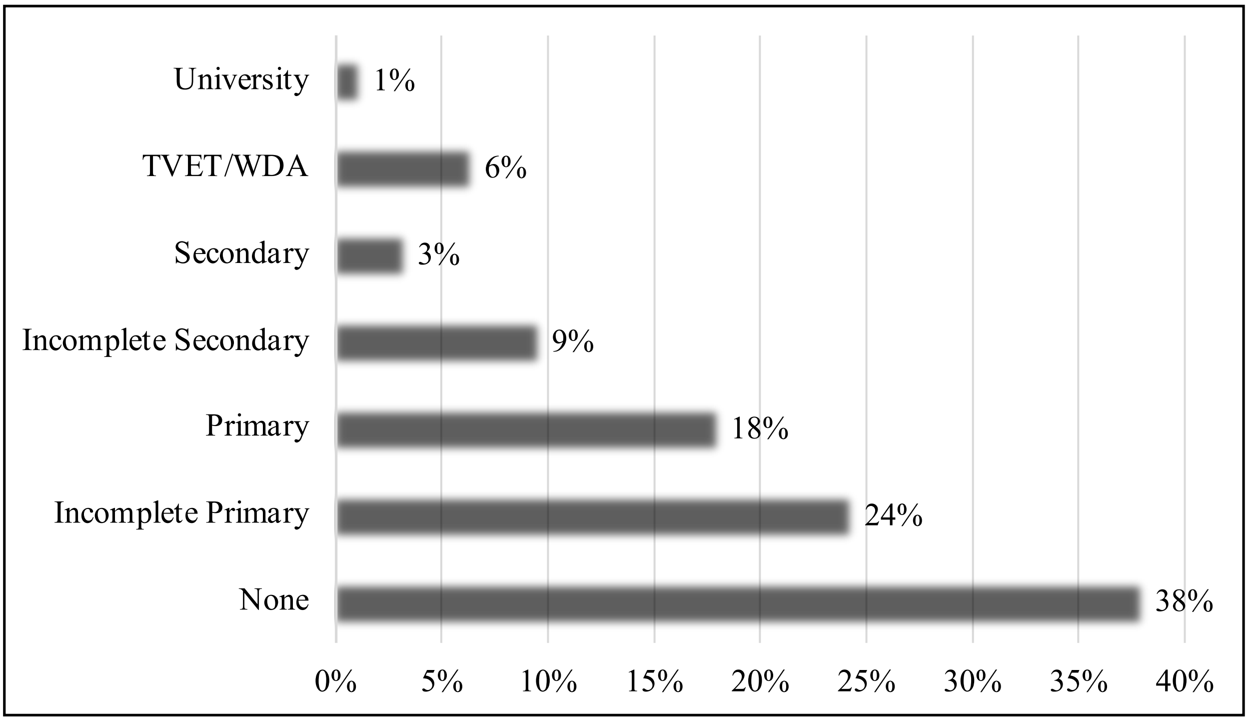

Figure 4: **Level of Education of Respondents**

Source: Field data (2025).

4.1.5. Occupation/Profession of Respondents

The spatial distribution of respondents overwhelmingly reflects the dominance of agriculture as the primary occupation, with 99% (94 out of 95) engaged in farming activities. This suggests that the surveyed population is predominantly rural and heavily reliant on agriculture for their livelihoods. Such a distribution is typical in many agrarian communities where farming forms the backbone of the local economy and sustains most households. The near-universal participation in agriculture indicates limited occupational diversity within the study area, which likely influences the community's vulnerability and adaptive capacity to environmental and climate-related changes, as their income and food security are tightly linked to agricultural productivity.

In contrast, only 1% of respondents reported trade or commerce as their occupation, highlighting the minimal presence of alternative livelihood options within the spatial area surveyed. This limited occupational diversification may reflect both the rural setting and the economic structure where non-farm income sources are scarce or underdeveloped. The spatial concentration of agricultural livelihoods underscores the need for targeted support in agricultural resilience and climate adaptation strategies, especially since any climate shocks would disproportionately impact the majority who depend solely on farming. This spatial pattern also suggests that interventions aimed at diversifying income sources or promoting trade could be valuable for enhancing local economic stability and reducing vulnerability.

4.1.6. Respondent by Migration

The pie chart shows that 94% of respondents have not migrated, while only 6% have. This indicates a high degree of settlement stability among smallholder farmers in Bahimba Wetland, Rulindo District. Such rootedness suggests that most residents are deeply tied to their land and agricultural livelihoods, which may increase their vulnerability to climate change (FAO, 2018). Rather than relocating, these farmers are likely to remain in place and cope with environmental challenges through local, on-site adaptation strategies (IPCC, 2022a). This makes it essential to understand their needs and capacities, especially in terms of access to climate-resilient farming techniques, water management, and diversified livelihoods (UNDP, 2016).

From a gendered perspective, the low migration rate may reflect differing socio-cultural and economic constraints that limit mobility, particularly for women. Women farmers are often more dependent on local land resources and face greater barriers to migration due to caregiving responsibilities, limited access to land tenure elsewhere, or lack of financial means. Consequently, their ability to adapt to climate impacts is closely tied to the resilience of local systems and community support structures. This insight underscores the importance of targeted, gender-sensitive adaptation interventions that strengthen local livelihoods rather than relying on migration as a response to climate stress (Djoudi et al., 2016).

4.2. Climate Change Exposure and Sensitivity

4.2.1. Climatic Conditions in the Study Area

4.2.1.1. Climatic Conditions in terms of Temperature Patterns

The spatial distribution of temperature across the Bahimba Wetland area, as the map illustrates the that average temperature across villages in a given sector, with temperature values ranging from 17.80°C to 18.24°C. The map uses a gradient of orange shades to represent temperature intervals, where lighter shades indicate lower temperatures and darker shades represent higher ones. Villages such as Kibamba and Kinihira ya Mbogo experience the highest average temperatures (18.16–18.24°C), while northern villages like Nyirambuga, Gihonga, Bukoro, Gasama and Kamuragi fall within the cooler range of 17.80–17.90°C. Sector boundaries and wetlands are clearly marked, aiding in understanding the geographic and environmental context. Notably, central villages like Mbogo and Tumba are labeled in magenta, possibly highlighting areas of specific interest or focus in the analysis. This map serves as a valuable tool for climate-related studies, development planning, and environmental monitoring at the local level.

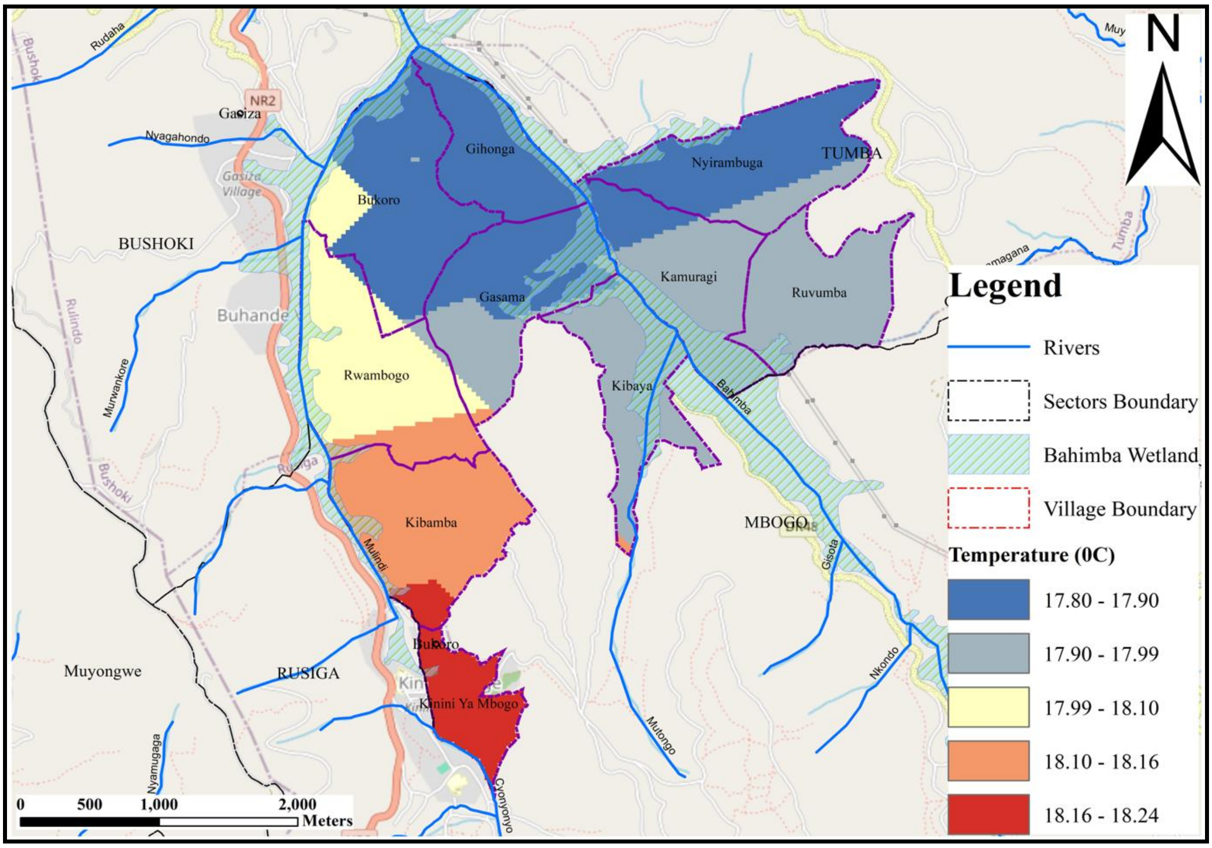

Figure 5: **Spatial Variation of Temperatures in the Study Area**

Source: (NLA, 2025).

The temperature variation observed in the Bahimba Wetland is consistent with findings from other research in similar agro-ecological zones, where slight spatial differences in temperature significantly affect agricultural dynamics. For instance, Pereira (2017) in the IPCC Fifth Assessment Report reported that even small shifts in mean temperature across East African landscapes can alter planting calendars, reduce yields, and increase vulnerability of subsistence farming systems, particularly in highland and wetland-adjacent areas. Similarly, (Rurangwa, 2021) found that temperature gradients within Rwanda's wetland ecosystems influence evapotranspiration rates and soil moisture retention, both of which are critical for smallholder farming and crop resilience.

Additionally, Olarewaju et al. (2025) emphasized that areas with minor temperature elevations, especially those transitioning from wetland to upland zones, often experience reduced crop performance due to higher water stress and increased pest incidence. This supports the notion that the southern part of the Bahimba Wetland, experiencing relatively higher temperatures, may be more vulnerable to heat-related crop stress compared to cooler northern zones. Furthermore, Gwambene et al. (2023) highlighted that in Rwanda, spatial temperature differences within small regions can translate into unequal impacts of climate change, affecting the efficiency of uniform agricultural interventions and necessitating localized adaptation planning.

Therefore, the spatial temperature gradient in the Bahimba Wetland underscores the need for micro-climate-based planning, including tailored cropping calendars, site-specific crop selection, and resource allocation, in line with research advocating for place-based adaptation strategies in rural Africa.

4.2.2. Climatic Conditions in terms of Rainfall Patterns

Rulindo receives 1326 mm (52.2 in) of rainfall per year, or 110.5 mm (4.4 in) per month. The driest weather is in July when an average of 14 mm (0.6 in) of rainfall (precipitation) occurs.

This map illustrates the spatial variation of precipitation across villages surrounding the Bahimba Wetland, highlighting key climatic conditions that directly influence the livelihoods of smallholder farmers in the area. The rainfall distribution, ranging from 1,222 mm to 1,276 mm, shows a clear gradient where western villages such as Bukoro, Rwambogo and Gihonga receive significantly higher rainfall (1,266–1,276 mm). In contrast, northeastern areas like Kamuragi, Ruvumba and Nyirambuga receive lower rainfall amounts (1,222–1,234 mm). This pattern suggests that farmers near the wetland benefit from more favorable moisture conditions for crop cultivation and livestock, potentially enhancing agricultural productivity and resilience to drought. However, the higher precipitation levels may also increase the risk of waterlogging or soil erosion, especially on sloped lands. Therefore, understanding these spatial rainfall differences is crucial for climate adaptation strategies, especially in tailoring water management and sustainable farming practices to support the smallholder farming systems around the Bahimba Wetland.

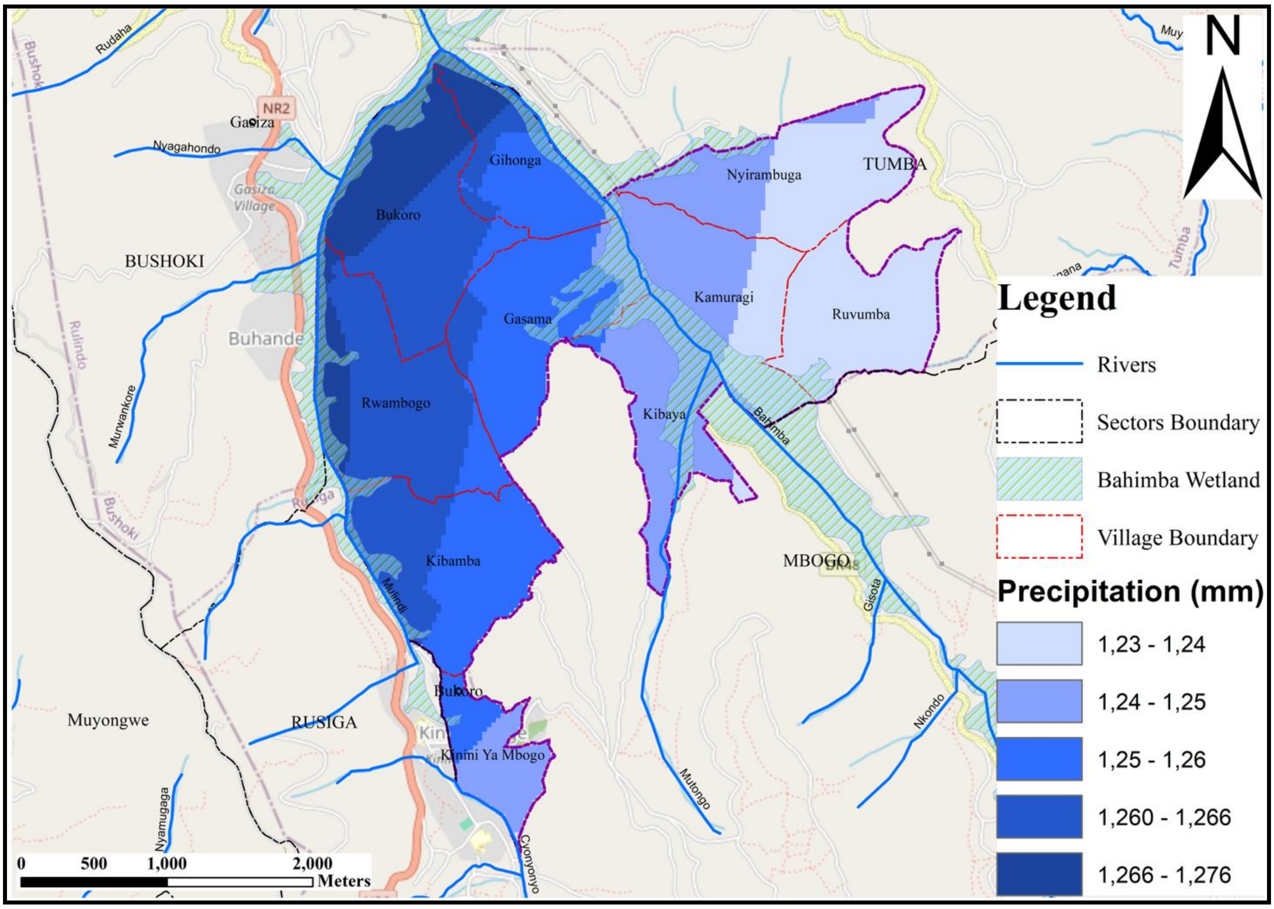

Figure 6: **Spatial Variation of Prepications in Bahimba Wetland**

Source: (NLA, 2025).

The variation in precipitation observed in the Bahimba Wetland is consistent with broader regional patterns reported in East Africa, where rainfall distribution is highly influenced by local topography, elevation, and land cover. Mugume et al. (2018) emphasize that in Rwanda and surrounding highland areas, orographic effects play a significant role in rainfall concentration, with elevated regions typically receiving more precipitation due to moisture-laden winds being forced upwards. This supports the observation of higher rainfall in the western and central parts of the wetland. Similarly, IPCC (2017), in the IPCC Fifth Assessment Report, highlighted that even small spatial differences in rainfall in East Africa can result in drastically different agricultural and hydrological outcomes, particularly in wetland ecosystems where water balance is crucial for farming, especially for crops dependent on consistent soil moisture.

Moreover, Mugabe (2008) argue that uneven rainfall distribution contributes to unequal agricultural productivity across smallholder landscapes, with wetter zones at risk of flooding and erosion, while drier areas may struggle with crop germination and water stress. The findings in Bahimba echo this challenge, emphasizing the need for location-specific water management strategies. Furthermore, Ndayisaba et al. (2021) observed that in Rwanda's wetland-based farming systems, spatial disparities in rainfall influence not only productivity but also the sustainability of soil and water conservation efforts, especially in regions undergoing climate variability.

4.2.3. Major Indicators of Change in the Study Area

4.2.3.1. Manifestations of Change in Temperature Patterns

The results from the table on the manifestations of change in temperature patterns in the Bahimba Wetland indicate that a majority of respondents (70.5%) identified various unspecified or localized forms of temperature change categorized as "Other," suggesting that community experiences of climate variability may extend beyond commonly recognized patterns. Meanwhile, 17.9% reported an increase in daily temperatures, highlighting a growing concern about warming trends in the area. Additionally, 10.5% observed longer dry seasons, which align with broader regional patterns of shifting rainfall and prolonged dry periods due to climate change. Only 1.1% reported intensification of aridity, indicating that while extreme dryness may not yet be widespread, its presence could signal emerging localized impacts. These findings underscore the importance of capturing diverse local perceptions to fully understand climate change manifestations, as communities may observe nuanced or compound effects not easily categorized within standard climate indicators.

Table 5: **Manifestations of Change in Temperature Patterns in the Study Area**

Manifestation of Change in Temperature Patterns	Frequency	%
Increase of daily temperature	17	17.9
Long dry season	10	10.5
Intensification of aridity	1	1.1
Other	67	70.5
Total	**95**	**100.0**

Source: Field data (2025).

4.2.3.2. Manifestations of Change in Rainfall Patterns

The results from Table 7 indicate that the most commonly observed manifestation of changes in rainfall patterns in the Bahimba Wetland is the occurrence of heavy and intensive rains, reported by a significant majority (87.4%) of respondents. This suggests a growing concern over the intensity of rainfall events, which can lead to flooding, soil erosion, and crop destruction, particularly in wetland farming areas. A smaller portion (8.4%) reported experiencing erratic and unpredictable rainfall, pointing to increasing variability in precipitation patterns that complicates agricultural planning. Only 1.1% of respondents noted delays in the onset of the rainy season, and 3.2% mentioned other unspecified changes. These findings underscore the community's heightened exposure to extreme weather events rather than gradual seasonal shifts, highlighting the urgent need for climate adaptation measures focused on water management, erosion control, and resilient agricultural practices.

Table 6: **Manifestations of Change in Rainfall Patterns in Bahimba Wetland**

Manifestation of Change in Rainfall Patterns	Frequency	Percent
Erratic and unpredictable rainfall	8	8.4
Delay of rainy season	1	1.1
Heavy and intensive rains	83	87.4

Other	3	3.2
Total	95	100.0

Source: Field data (2025).

The findings from Table 7 are consistent with broader research across East Africa, where communities increasingly report heightened rainfall intensity as a primary manifestation of climate change. Shongwe et al. (2009), in their assessment of rainfall trends in the region, found a notable rise in the frequency of extreme precipitation events, particularly during the short rainy seasons, which directly contributes to flooding and agricultural disruption. The 87.4% of respondents in Bahimba identifying heavy and intensive rains aligns with this trend and reflects the shifting nature of rainfall from predictable seasonal patterns to more erratic and extreme occurrences. Similarly, Thornton et al. (2014) emphasized that the intensification of rainfall in highland and wetland areas of East Africa is not only increasing runoff and erosion but also exacerbating food insecurity among smallholder farmers who rely on rainfall for production.

The 8.4% of respondents who reported erratic and unpredictable rainfall also mirrors findings by (De la Paix et al., 2011) in Rwanda, where farmers noted challenges in forecasting rain, leading to delays in planting and losses in agricultural yields. This unpredictability makes traditional knowledge and historical weather patterns less reliable for planning. Additionally, the low percentage (1.1%) of respondents reporting delayed rainy seasons suggests that while seasonal shifts are occurring, the community is currently more impacted by extreme rainfall events than timing variations—similar to patterns observed by (Cooper et al., 2020) in climate vulnerability assessments in Eastern and Southern Africa.

Collectively, these findings reinforce the need for localized adaptation strategies that address the growing threat of intense rainfall events, including improved drainage systems, early warning mechanisms, and the promotion of soil conservation practices tailored to high-risk wetland zones.

4.3. Vulnerability to Climate Change Impacts in Bahimba Wetland

4.3.1. Types of Climate-induced Disasters in the Study Area

The data presented show that floods are the most frequently reported climate-induced disaster affecting smallholder farmers in the Bahimba Wetland, accounting for 65.26% of responses. This high percentage highlights the critical role of water-related hazards in shaping agricultural production and rural livelihoods in the region (MIDIMAR, 2015a; MINAGRI, 2024). Given the wetland's ecological setting and topography, floods pose a serious threat to crop yields, livestock, and farm infrastructure, undermining food security and household income (Mutuyimana, 2015). The spatial distribution of respondents experiencing floods suggests that low-lying and river-adjacent plots are particularly vulnerable, exacerbating gendered inequalities, as women often cultivate marginal lands closer to flood-prone zones due to limited access to productive and safer farmlands (Bizoza, 2016).

In contrast, soil erosion affects 23.16% of respondents, indicating that hillside and sloping farmlands around the wetland basin face significant degradation challenges. Landslides (6.32%) and other hazards (2.11%) represent localized but consequential risks (REMA, 2021). These findings underscore the differentiated spatial impacts of climate change on agricultural systems in Bahimba, which intersect with gender dynamics: women, who generally manage smaller plots with less technical support, face disproportionate impacts from soil erosion and floods (UN Women, 2021). This context necessitates gender-responsive adaptation strategies that promote flood-resilient farming practices, improved soil conservation measures, and inclusive decision-making processes to strengthen the adaptive capacity of both men and women smallholder farmers (CEDAW, 2022; FAO, 2020).

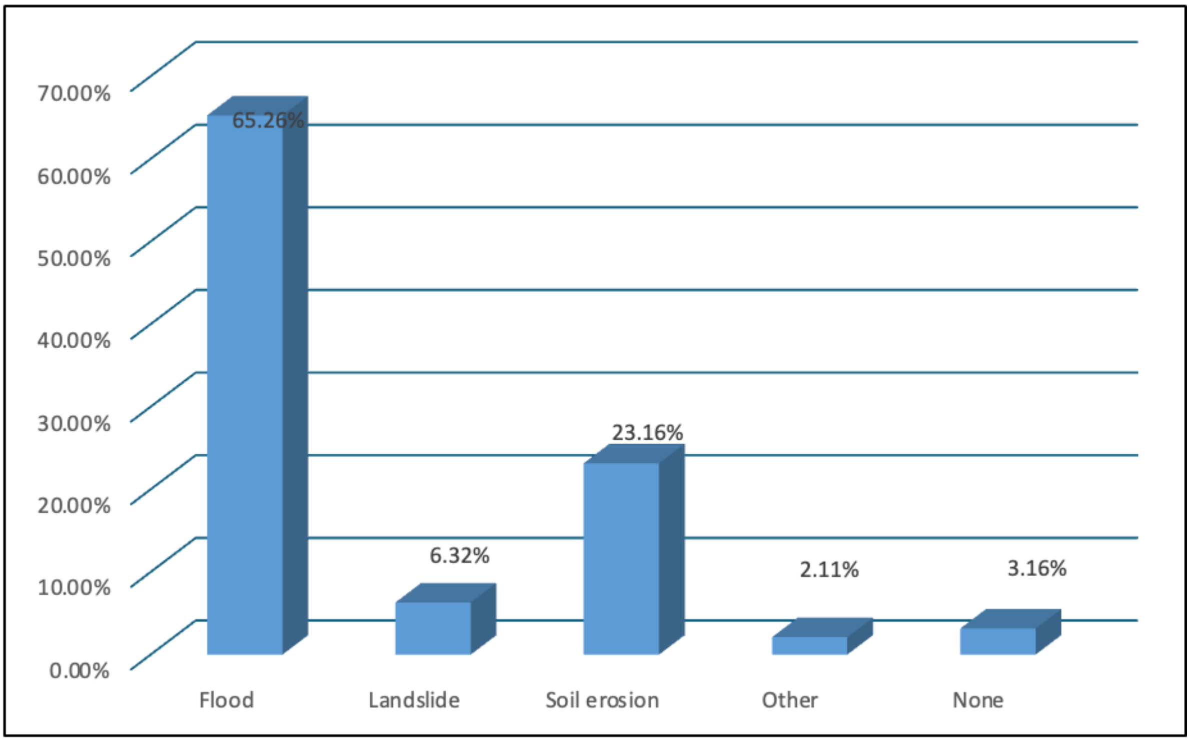

Figure 7: **Types of Climate-induced-disasters in the Study Area**

Source: Field data (2025).

4.3.2. Level of Vulnerability to Flooding in the Study Area

Rwanda experiences varying levels of flooding, particularly in low-lying wetlands, urban centers, and mountainous regions during the rainy seasons. The combination of intense rainfall, steep topography, poor drainage infrastructure, and increased land use changes such as deforestation and unplanned settlements has heightened flood risks in areas like Kigali, Rubavu, Nyabihu, and parts of the Southern Province. These floods often result in significant damage to infrastructure, homes, and agricultural lands, posing recurrent challenges to community livelihoods and national disaster management efforts (MIDIMAR, 2015a; REMA, 2019).

The figure 8 indicated the flooding susceptibility map reveals that the majority of the study area (54.3%) falls under the Very Low flood risk zone, indicating that over half the region is relatively safe from severe flooding impacts. However, Moderate flood risk areas cover 20.9%, while Low risk zones make up 19.4%, suggesting a substantial portion of the landscape still faces some degree of vulnerability. Critically, Very High and High flood-prone zones, although smaller in coverage (3.5% and 1.9% respectively), are concentrated in specific regions likely areas with low elevation, high drainage density, or proximity to water bodies indicating potential hotspots where urgent flood mitigation measures should be prioritized.

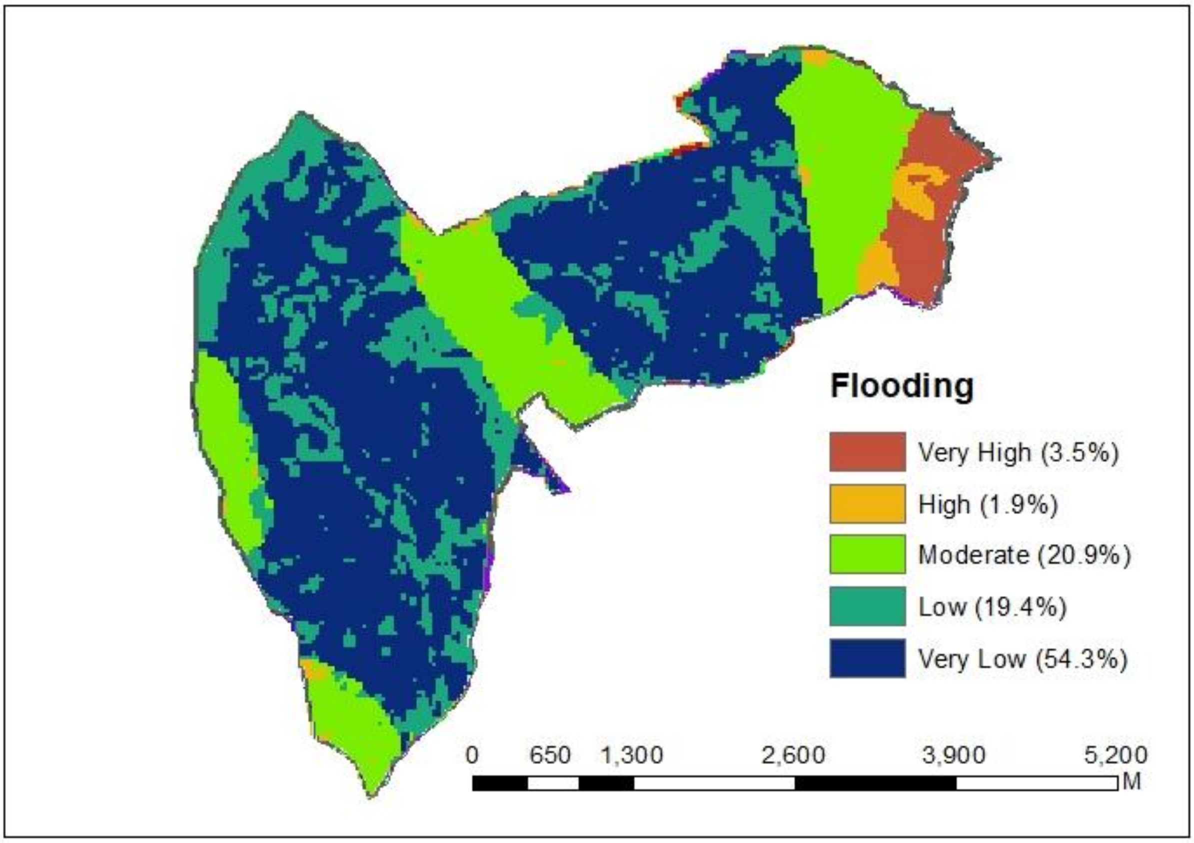

Figure 8: **Vulnerability to Flooding in Bahimba Wetland**

Source: (NLA, 2025)

4.3.3. Level of Vulnerability to Soil Erosion in the Study Area

Soil erosion is the most serious environmental problem in many catchments' areas in Rwanda. The main factors affecting the amount of soil eroded include land use and vegetation cover, topography, soil and climate (Byizigiro et al., 2020).

Table 7: **Level of Vulnerability to Soil Erosion around Bahimba Wetland**

Level of Erosion	Numeric Range (t/ha/year)	Soil Loss (Area)	Soil Loss (%)
Low	0-2	16.31	0.99
Moderate	2-7	1.48	0.09
High	7-16	0.62	0.04
Very High	16-222	0.20	0.01
Extremely high	222-16523	1630.62	98.87

Source: Field data (2025).

The map and table highlight the severity of soil erosion within the study area, classified into five categories based on annual soil loss rates (t/ha/year). The vast majority of soil loss 98.87% occurs in areas classified as experiencing "Extremely High" erosion (222–16,523 t/ha/year), covering a total area of 1,630.62 ha. In stark contrast, all other erosion categories (Low, Moderate, High, and Very High) together account for less than 1.2% of total soil loss, despite being spread across multiple hectares. This striking imbalance suggests that while extreme erosion is concentrated in a smaller proportion of the landscape, its impact is disproportionately large and potentially catastrophic for soil health and agricultural productivity.

The Low erosion category, ranging from 0–2 t/ha/year, covers 16.31 ha, but only contributes 0.99% to the total soil loss, indicating that although such areas are relatively extensive compared to others, they are not the main contributors to land degradation. Categories such as Moderate (2–7 t/ha/year) and High (7–16 t/ha/year) cover even less area (1.48 ha and 0.62 ha respectively), with negligible contributions to overall erosion. These findings underscore the urgent need for targeted soil conservation measures in the extremely high erosion zones, as they are responsible for nearly all of the soil loss in the area, threatening sustainability, water quality, and downstream ecosystems.

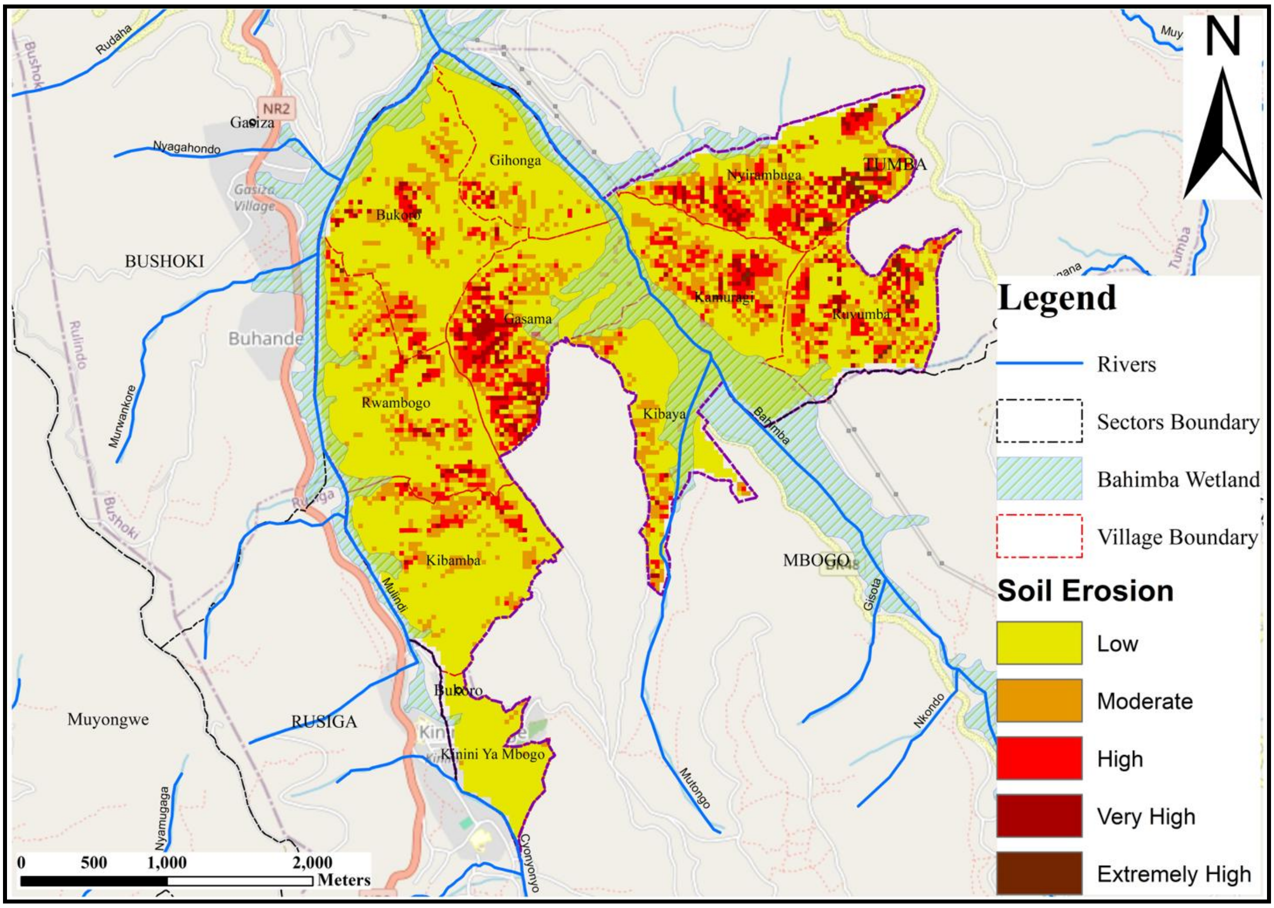

Figure 9: **Vulnerability to Soil Erosion in and around Bahimba Wetland**

Source data: (NLA, 2025)

The alarming predominance of "Extremely High" soil erosion (222–16,523 t/ha/year) across the Bahimba Wetland area, responsible for 98.87% of total soil loss, is consistent with findings in other parts of East Africa where unsustainable land use practices, steep slopes, and heavy rainfall have exacerbated erosion risks. Similar patterns were observed by (Lal, 2003), who noted that soil erosion in developing countries is often most severe on degraded lands with poor vegetative cover and high runoff potential. In Rwanda specifically, (Nsengiyumva et al., 2019) found that extremely high erosion hotspots are largely concentrated in agricultural zones on steep slopes, especially where terracing or agroforestry practices are absent. These areas contribute significantly to sedimentation in wetlands and rivers, degrading water quality and reducing arable land productivity. Moreover, (Haregeweyn et al., 2017), in a comprehensive study across the Ethiopian highlands, similarly highlighted that a small fraction of land typically contributes to a vast proportion of total soil loss, suggesting that strategic, localized interventions such as check dams, contour farming, and vegetative buffer zones can have an outsized impact on soil conservation. The minimal contribution of the Low, Moderate, and High erosion categories in Bahimba Wetland reinforces the principle of prioritizing high-impact areas for intervention, as advocated by (Morgan, 2009) in his work on soil erosion modeling. The findings emphasize the necessity for immediate, site-specific soil conservation planning and sustainable land management practices to prevent further degradation of both land and downstream ecosystems.

4.3.4. Level of Vulnerability to Landslides in the Study Area

The landslides are the mostly dominated in Rwanda, 40% of the country's population have a moderate to very high level of susceptibility to landslide; 43% of health facilities in the country face a high level of susceptibility to landslides (MIDIMAR, 2015b).

The landslide susceptibility map of Bahimba Wetland in Rulindo District reveals a significant spatial variation in landslide risk across the sectors of Mbogo and Tumba**.** The majority of the area (56.83%) is classified under low landslide risk, predominantly concentrated in central and southern zones. However, a considerable portion (36.76%) falls under moderate risk, while smaller areas show high (3.55%) and very low (2.86%) landslide risk. The presence of high-risk zones, especially in hilly or steep areas, suggests heightened vulnerability to slope instability an issue increasingly exacerbated by climate change impacts such as intense and erratic rainfall. These physical threats pose direct challenges to agricultural production, particularly for smallholder farmers who rely on hillside cultivation. Soil displacement and land degradation in high-risk zones can lead to decreased yields, loss of arable land, and increased food insecurity.

When analysed through a gendered lens, the map further underscores the differentiated impacts of climate-induced disasters on rural livelihoods. Women in smallholder farming communities often cultivate marginal lands, including those within or near landslide-prone zones, due to gendered constraints in accessing fertile or secure land. In the context of Bahimba Wetland, climate change-induced landslides not only damage crops but also intensify the burdens on women, who are typically responsible for food production and household resilience. As climate variability continues to escalate, gender-sensitive adaptation strategies are crucial such as promoting women's access to early warning systems**,** land-use planning training**,** and climate-smart agricultural practices. Supporting women farmers in these high-risk zones with targeted interventions is key to sustaining agricultural productivity and securing livelihoods amid growing climate threats.

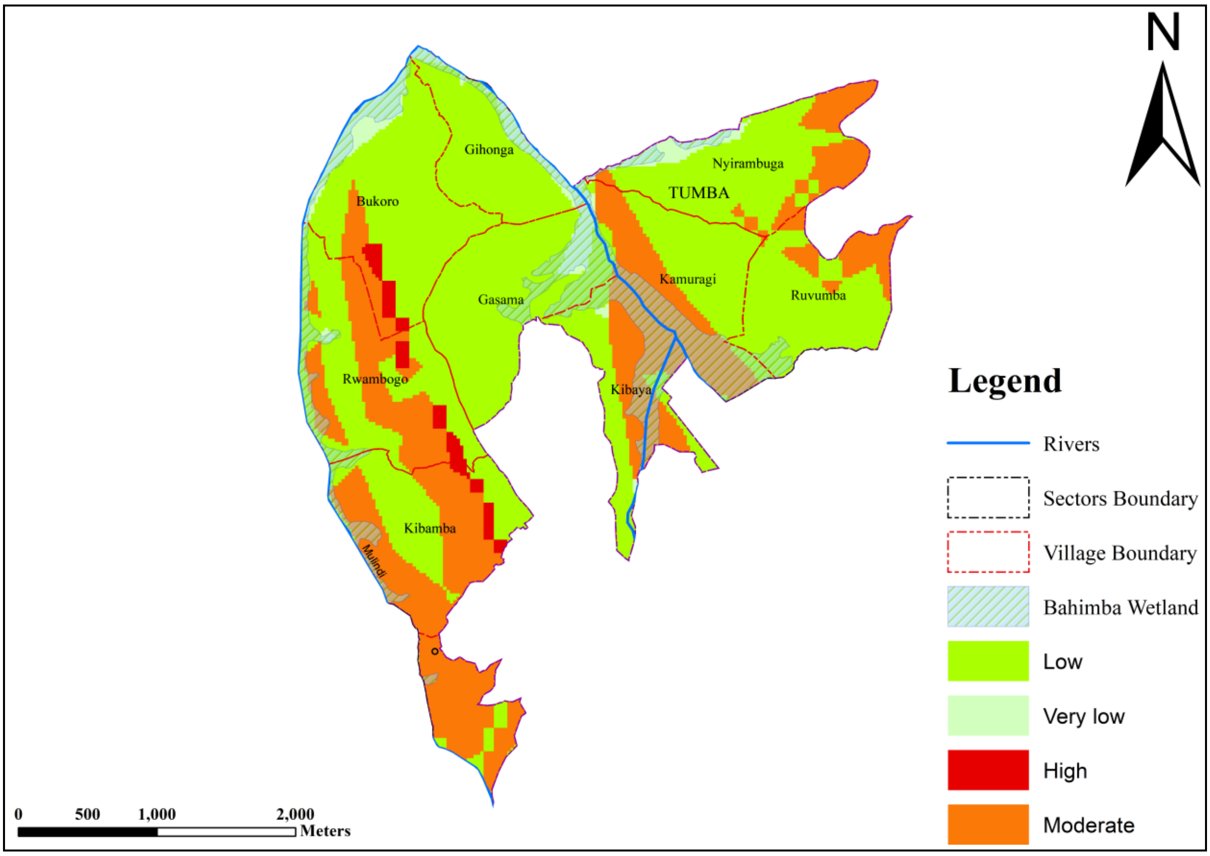

Figure 10: **Vulnerability to Landslides around Bahimba Wetland**

Source: (NLA, 2025).

4.3.5. Losses and Damages caused by Climate-induced Disasters

The distribution of respondents by gender in relation to reported losses and damages highlights noticeable differences in experiences and impacts among male and female respondents. Out of a total of 95 respondents, 39 were male and 56 were female. Among male respondents, the most frequently reported loss was crops destroyed and/or damaged (30 cases), followed by injuries of people (3 cases), houses destroyed and/or damaged (3 cases), and infrastructure destroyed and/or damaged (3 cases). Notably, there were no reports of deaths among males. This distribution suggests that while men reported multiple categories of losses and damages, their primary impact centred on agricultural losses, reflecting perhaps their direct involvement in agricultural activities or landholding roles within the community (Doss et al., 2018; FAO, 2011).

For female respondents, the highest reported loss was also crops destroyed and/or damaged, accounting for 50 cases, indicating significant vulnerability in agricultural livelihoods. Additionally, female respondents reported 2 deaths, 2 injuries, 1 case of houses destroyed and/or damaged, and 1 case of infrastructure destroyed and/or damaged. The presence of reported deaths among female respondents suggests that women and their households might be more exposed to severe consequences during climate-induced events, potentially linked to their roles in caregiving or domestic responsibilities that keep them in vulnerable locations during disasters (Alston, 2014; Bradshaw & Fordham, 2013). Overall, the data reveal gendered differences in reported impacts, underscoring the importance of considering gender in designing targeted adaptation and disaster risk reduction strategies (UN Women, 2022).

Table 8: **Losses and Damages by Climate-induced Disasters in Bahimba Wetland**

Gender	Type of Loss and/or Damage					Total
	Death of People	Injury of People	Destruction and/or Damage of Houses	Destruction and/or Damage of Crops	Destruction and/or Damage of Infrastructures	
Male	0	3	3	30	3	**39**
Female	2	2	1	50	1	**56**
Total	**2**	**5**	**4**	**80**	**4**	**95**

Source: Field data (2025).

4.3.6. Crop Damages Attributable to Climate-Induced Disasters

The distribution of respondents concerning the types of crops destroyed and/or damaged reveals that maize was overwhelmingly the most affected crop, accounting for 81.1% of the reported damages. This high proportion suggests that maize is the dominant crop cultivated by smallholder farmers across the study area, reflecting its importance as a staple food and income source in rural livelihoods (FAO, 2021; MINAGRI, 2022). The widespread maize cultivation and subsequent vulnerability to climate-related hazards such as landslides, heavy rainfall, and soil erosion underscore how environmental risks are not evenly distributed but concentrated in areas where maize farming is predominant. This distribution points to low-lying and slope-prone zones especially in rural and hilly regions like Bahimba wetland and parts of the Kiyumba Sector as hotspots for crop vulnerability due to their agro-ecological characteristics and limited resilience infrastructure (REMA, 2021).

In contrast, crops like Irish potatoes (12.6%), vegetables (3.2%), and other unspecified types (3.2%) showed considerably lower levels of damage, suggesting a more limited spatial distribution or smaller cultivation area. These crops may be grown in more localized plots or under specific agro ecological conditions, such as cooler highland areas for Irish potatoes or irrigated valleys for vegetables (NISR, 2022c). The lower percentage of damage could also reflect better resilience measures applied to these crops, or simply less exposure due to smaller planting areas. Therefore, the spatial distribution of respondents highlights both the prominence of maize cultivation and the uneven risk exposure of crop types, with implications for designing targeted climate adaptation strategies and agricultural extension support in the most vulnerable farming zones (MINAGRI, 2022).

Table 9: **Primary Crops Severely Affected by Climate Risks**

Crops Affected	Frequency	%
Maize	77	81.1
Irish Potatoes	12	12.6
Vegetables	3	3.2
Other	3	3.2
Total	**95**	**100.0**

Source: Field data (2025).

The distribution of respondents experiencing crop failure due to climate factors indicates a significant prevalence of this challenge across the study area. A majority (57.9%) of respondents reported that they "frequently" experience crop failure, suggesting that most live in areas highly vulnerable to climate-related risks such as erratic rainfall, prolonged droughts, or floods.

Additionally, 20% of respondents indicated that crop failure occurs "always" in their farming activities, which points to a persistent exposure to adverse climatic conditions. These two categories together represent nearly 78% of the total sample, highlighting a critical hotspot of agricultural vulnerability, likely concentrated in lowland or wetland areas like Bahimba in Rulindo District, where climate sensitivity is intensified by topographic and ecological conditions (Gaspard Rwanyiziri, 2019).

Conversely, only a small proportion of respondents reported minimal climate-related crop failure, with 1.1% experiencing it "rarely" and 21.1% "occasionally." This may indicate that certain parts of the study area benefit from relatively stable microclimates or more resilient agro-ecological conditions, such as access to irrigation, improved soil fertility, or adaptive farming techniques (NISR, 2022a; World Bank, 2020). These spatial variations in experience reveal underlying disparities in climate resilience and adaptive capacity. Linking these patterns to gendered adaptation strategies may further expose how men and women differentially access resources and technologies that mitigate crop failure risks, emphasizing the need for localized and inclusive climate-smart agricultural interventions (Twyman et al., 2014).

Table 10: **Farmers' Perceptions on Crop Failure due to Climate Factors**

Crops failure	Frequency	%
Rarely	1	1.1
Occasionally	20	21.1
Frequently	55	57.9
Always	19	20.0
Total	**95**	**100.0**

Source: (Field data, 2025).

The findings from Table 10 indicate that the majority of farmers perceive crop failure due to climate factors as a frequent or consistent challenge. This perception aligns with several studies conducted in sub-Saharan Africa, where climate variability and extreme weather events have increasingly disrupted agricultural productivity. For instance, in Rwanda, studies have highlighted that prolonged droughts, irregular rainfall, and floods have become more common, contributing significantly to reduced yields and increased vulnerability among smallholder farmers (Bizimana et al., 2021). These environmental stressors not only affect crop quantity but also influence the quality and timing of harvests, further exacerbating food insecurity in rural communities.

Comparing these perceptions with other regions, similar patterns emerge. In Ethiopia, Deressa et al. (2009) found that farmers were highly aware of the impacts of climate change, particularly through declining rainfall and increasing temperatures, which directly correlated with crop failure. Likewise, in Uganda, Mubiru et al. (2018) reported that farmers attributed declining crop yields to shifting rainfall patterns and unpredictable weather, which have made traditional farming calendars unreliable. Such studies reinforce the notion that smallholder farmers across East Africa are witnessing and responding to the tangible effects of climate-related disruptions on agriculture.

Furthermore, the consistency in farmers' perceptions of crop failure suggests a growing recognition of climate change as a critical threat to subsistence agriculture. According to Below et al. (2012), when farmers frequently observe reduced harvests, they tend to attribute these changes to climate-induced causes rather than to isolated agronomic issues. This awareness is crucial for informing adaptation strategies and policy interventions. It highlights the urgent need for government and development agencies to strengthen climate-resilient agricultural practices, improve early warning systems, and promote diversified livelihood options to mitigate the risks associated with climate variability.

4.3.7. Impact of Climatic Change on crops production

The distribution of respondents in relation to the impacts of climate change on crops reveals notable gendered patterns that are essential to understanding rural vulnerabilities. Out of the total 95 respondents, a higher proportion were female (56) compared to male (39), highlighting the central role of women in agricultural activities within the study area (Bapfakurera et al., 2025). The most frequently reported impact among both genders was crop failure, with 33 women and 20 men citing this as a major consequence, suggesting that climate change is severely disrupting agricultural productivity across the community. This reflects the acute sensitivity of smallholder farmers especially women to erratic weather patterns, prolonged dry spells, and unreliable rainfall that directly affect crop performance (Bapfakurera et al., 2025).

Additionally, while men predominantly reported decreased yields (10) and food insecurity (6) as critical issues, women were more likely to report pest and disease outbreaks (7) and crop failure. This variation may be influenced by the different roles and responsibilities each gender assumes in farming systems; women, who are often responsible for subsistence farming and food preparation, are more directly affected by changes in food quality and availability (Jost et al., 2016). The spatial distribution also implies a gendered difference in perception and experience of crop damage, with women experiencing a broader range of climate-related agricultural challenges. These insights are critical for designing targeted adaptation strategies that are both gender-sensitive and location-specific in addressing climate-induced crop losses in rural Rwanda.

Table 11: **Impacts of Climate Change on Crops Production**

Gender	Impacts of Climate Change on Crops					Total
	Crop Failure	Decreased Yields	Pest/Disease Outbreak	Soil Degradation	Food Insecurity	
Male	20	10	2	1	6	**39**
Female	33	7	7	2	7	**56**
Total	**53**	**17**	**9**	**3**	**13**	**95**

Source: Field data (2025).

4.4. Climate Vulnerability, Gender and Rural Livelihoods

4.4.1. Gender Dimension in Farming Activities among Smallholder Farmers

The results from Table 12 reveal a significant gender disparity in farming activities among smallholder farmers. Out of the 95 respondents, 57.9% identified women as the primary individuals responsible for farming, while only 14.7% indicated that men take on this role. Additionally, 27.4% of respondents reported that both men and women equally share farming responsibilities. These findings suggest that women are the dominant contributors to agricultural labor in the study area, reflecting the feminization of agriculture commonly seen in rural regions of Rwanda. The lower representation of men may be attributed to factors such as male outmigration, involvement in off-farm employment, or traditional gender roles. The relatively high percentage of shared responsibility also points toward a gradual shift in gender dynamics within households, which could foster more collaborative decision-making and enhance resilience in agricultural practices.

Table 12: **Gender Proportion in Farming Activities among Smallholder Farmers**

Type of Gender	Frequency	%
Male	14	14.7
Female	55	57.9
Both equally	26	27.4
Total	**95**	**100**

Source: Field data (2025)

The observed gendered distribution of farming responsibilities in the Bahimba wetland aligns with broader trends identified in other regions of sub-Saharan Africa, where women play a central role in agricultural production. Similar findings have been reported by Doss (2018), who noted that despite women contributing significantly to agricultural labor, their roles are often underrecognized, and they face persistent disparities in access to resources and decision-making power. The high proportion of women identified as primary farmers in the study area reflects this ongoing "feminization of agriculture," particularly driven by male outmigration and shifting labor dynamics, as highlighted by (Leder, 2022) in their study on gender roles in rural livelihoods.

Additionally, (Carr & Thompson, 2014) emphasize that gender-differentiated roles in agriculture influence vulnerability and adaptation capacity in the context of climate change. The fact that women are disproportionately responsible for farming means they are more directly affected by climate-induced risks, which reinforces the need for targeted, gender-sensitive adaptation interventions. For instance, if women lack access to early warning systems, training, or financial resources, their ability to adapt to climate variability such as unpredictable rainfall or land degradation—is significantly compromised. Furthermore, the finding that over a quarter of households reported shared responsibilities between men and women may indicate progress toward more equitable gender relations in some contexts. This trend is supported by (Farnworth et al., 2016), who argue that joint decision-making in farming households can lead to more inclusive and resilient agricultural practices, especially when supported by inclusive policy frameworks and community-based interventions.

4.4.2. Level of Participation in Decision-making among Women Farmers

In Rwanda, women play a vital role in the agricultural sector, contributing significantly to food production and household livelihoods. However, their level of participation in decision-making remains limited due to socio-cultural norms, gender-based inequalities, and restricted access to resources such as land, credit, and agricultural extension services. Despite progressive gender-sensitive policies implemented by the Rwandan government, such as the National Gender Policy and the Land Law promoting equal ownership rights, many women farmers still have minimal influence over agricultural decisions at the household and community levels. Studies have shown that while women are heavily involved in daily farming activities, decisions related to crop selection, resource allocation, and income use are often dominated by male counterparts (Mutabazi et al., 2015). This disparity hinders women's ability to fully benefit from agricultural opportunities and limits the effectiveness of climate adaptation and development initiatives. Strengthening women's participation in decision-making processes is therefore essential for achieving inclusive and sustainable agricultural development in Rwanda.

The distribution of respondents regarding women's participation in decision-making on farming activities and adaptation strategies to climate change reveals notable gender differences. Among male respondents, a majority (23 out of 39) indicated that women do participate in decision-making, while 7 said no and 9 said sometimes. This suggests that men generally perceive women's involvement positively, though with some variability. Conversely, female respondents showed a different pattern: only 10 women affirmed consistent participation, 8 disagreed, but a substantial number 38 women reported that women sometimes participate in decision-making. This indicates that women themselves experience or perceive their participation as more conditional or limited, reflecting possible spatial or social constraints that influence how actively women engage in farming decisions and climate adaptation (Ampaire et al., 2017).

This distribution suggests spatial and social dynamics influencing women's empowerment in farming communities. The relatively higher "sometimes" responses among women may reflect areas or contexts where women's involvement is situational or dependent on factors such as household power relations, local customs, or access to resources (Jost et al., 2016). The difference between male and female perceptions could also point to gendered disparities in access to decision-making forums or differences in recognizing what counts as meaningful participation. Such spatial variation in decision-making roles highlights the importance of targeted interventions that consider local cultural and gender dynamics to enhance women's consistent involvement in climate adaptation strategies and farming decisions across different communities (FAO, 2011; Habtezion, 2016).

Table 13: **Women' Participation in Decision-making for Farming related Activities**

	Yes	**No**	**Sometimes**	**Total**
Male	23	7	9	**39**
Female	10	8	38	**56**
Total	**33**	**15**	**47**	**95**

Source: Field data (2025).

4.5. Gendered Adaptation Strategies to Reduce CC Impacts

4.5.1. Level of Awareness about Adaptive Strategies to Mitigate the Adverse Effects of CC

The distribution of respondents who have taken action to adapt to climate change effects reveals a uniform engagement across the surveyed area, as indicated by the 100% response rate of 95 participants affirming adaptation efforts. This complete participation suggests a widespread recognition of climate change impacts within the community, motivating proactive behaviour regardless of geographic location. Such uniformity in response may reflect effective dissemination of climate change information and adaptive strategies through local networks, policies, or community-led initiatives (Charity et al., 2021; Magesa et al., 2023), ensuring that individuals throughout the area are equally aware and involved in addressing climate risks.

Moreover, this spatially comprehensive adaptation response highlights the potential homogeneity in exposure or vulnerability to climate change effects across the study region. It may imply that environmental changes such as altered rainfall patterns, temperature variability, or land degradation are perceived consistently by residents in various locations, prompting similar adaptive behaviours (Twyman et al., 2011). This spatial pattern is crucial for policymakers and development agencies as it indicates that adaptation programs could be uniformly implemented, though further spatially disaggregated data would help tailor interventions to specific local needs or conditions within the broader community (Aboniyo & Mourad, 2017).

4.5.2. Smallholder Farmers' Strategies to Adapt to Climate-induced Disasters

The distribution of respondents regarding the strategies they used to adapt to climate or environmental challenges reveals a clear preference pattern concentrated largely on changing planting dates. With 83.2% of the respondents adopting this approach, it suggests that most smallholder farmers across the surveyed area are adjusting their agricultural calendar to better cope with shifting rainfall patterns or temperature variations. This widespread adoption could be linked to localized climatic variability influencing planting seasons, especially in areas vulnerable to drought or unpredictable rains. The dominance of this strategy highlights its accessibility and perceived effectiveness among farmers dispersed throughout the region (Below et al., 2010; Nhemachena & Hassan, 2007).

In contrast, other strategies such as soil conservation and mixed cropping are much less frequently adopted, each accounting for only 8.4% of respondents. This lower uptake may reflect spatial variability in both awareness and resource availability, as soil conservation practices often require more labor, knowledge, or inputs that might be limited in certain locations. Similarly, mixed cropping might be less practiced in areas where monoculture is traditionally dominant or where land size constraints limit diversification. The spatial pattern thus indicates that while the majority have embraced relatively simple, timing-based adaptations, more resource-intensive or complex strategies remain limited and potentially concentrated in specific pockets where enabling conditions exist (Bryan et al., 2013; Deressa et al., 2009).

Table 14: **Strategies used to Reduce the Adverse Effects of Climate-induced Disasters**

Strategies	Frequency	%	Valid (%)	Cumulative (%)
Changing Planting Dates	79	83.2	83.2	**83.2**
Soil Conservation	8	8.4	8.4	**91.6**

Mixing Crops	8	8.4	8.4	**100**
Total	**95**	**100**	**100**	

Source: Field data (2025).

4.5.3. Major Challenges in Adapting to CC Effects

The distribution of respondents facing challenges in adapting to climate change effects reveals a predominant concern regarding the lack of knowledge, which accounts for 83.2% of the reported challenges. This high percentage suggests that across the surveyed areas, there is a widespread deficiency in awareness or understanding of climate change impacts and appropriate adaptation measures (Bryan et al., 2013). Such a gap in knowledge could be especially pronounced in rural or less accessible regions where extension services, education, and information dissemination might be limited. The dominance of this challenge across the spatial distribution indicates that many communities are struggling to access relevant climate information or training, which hampers their ability to develop effective local adaptation strategies (IPCC, 2022b).

In contrast, financial constraints and inadequate technical support each represent 8.4% of the challenges reported by respondents, highlighting secondary but significant spatial patterns. Areas where lack of finance is more frequently cited may correspond to poorer or more economically vulnerable zones where residents lack resources to invest in adaptive technologies or practices (Below et al., 2012). Meanwhile, inadequate technical support likely reflects regions with limited government or NGO presence, where access to technical assistance, infrastructure, or institutional support is insufficient (Ampaire et al., 2017). Together, these findings suggest that while knowledge gaps are the most pervasive barrier across the spatial landscape, financial and institutional weaknesses are also spatially concentrated challenges that need targeted interventions to enhance adaptive capacity in the face of climate change.

Table 15: **Identified Challenges in Adapting to CC Effects**

Challenges	**Frequency**	**%**	**Valid (%)**	**Cumulative (%)**
Lack of Knowledge on CC	79	83.2	83.2	**83.2**
Lack of Financial Support	8	8.4	8.4	**91.6**

Inadequate Technical Support	8	8.4	8.4	**100.0**
Total	**95**	**100.0**	**100.0**	

Source: Field data (2025).

4.5.4. External Support for Climate Adaptation of Smallholder Farmers

The distribution of respondents regarding external support from the government and its partners on climate change adaptation for smallholder farmers reveals a significant gap in assistance. Out of 95 respondents, only 11.6% reported receiving any form of support, while a striking 88.4% had not received such aid. This distribution suggests that external interventions related to climate adaptation are either highly localized or inequitably distributed, with the majority of smallholder farmers especially those in remote or marginalized areas being excluded from government or partner-led initiatives. Such disparities hinder the resilience of rural communities and emphasize the urgent need for more inclusive and widespread support strategies.

4.5.5. Kind of support do women need most to adapt effectively to climate change

The distribution of respondents regarding the kind of support women need most to adapt effectively to climate change reveals a striking pattern of limited demand for specific external assistance. Out of the total 95 respondents, an overwhelming 89.5% indicated that they do not require any particular support, while only 10.5% expressed a need for training. This suggests that most women across the surveyed area may either feel confident in their current adaptation strategies or possibly lack awareness or access to resources that could enhance their resilience (Anjum & Aziz, 2025; CARE International, 2019; Jost et al., 2016). The low frequency of requested training could also indicate spatial clusters where outreach and capacity-building efforts have yet to reach or where women perceive adaptation as a personal or community responsibility rather than requiring formal intervention (MINIRENA, 2016; Munyazikwiye & Michaelowa, 2022).

This distribution implies that adaptation support needs are not uniformly recognized or demanded across the study area, possibly reflecting varying levels of exposure to climate risks, socioeconomic conditions, or cultural factors influencing women's perceptions. Areas with a higher proportion of women requesting training may correspond to locations more vulnerable to climate impacts or with limited traditional knowledge transfer. Conversely, the large majority reporting no need for support could reflect either effective existing coping mechanisms in certain localities or barriers such as lack of information, resources, or trust in external assistance (NAP-Rwanda, 2021; REMA, 2022). Understanding this spatial pattern is crucial for targeting adaptive capacity-building interventions effectively, ensuring that training programs are offered where they are most needed and accepted by women in different communities.

4.5.6. Climate Change Adaptation Strategies by Gender-sensitive

The distribution of respondents regarding whether adaptation strategies to climate change should be designed separately for men and women reveals a unanimous perspective across the surveyed area. All 95 respondents, representing 100% of the valid sample, agreed that adaptation strategies ought to be gender specific. This indicates a strong and consistent recognition among the community that men and women experience climate change impacts differently and therefore require tailored approaches to effectively address their unique vulnerabilities, needs, and capacities (Republic of Rwanda, 2022; UNFCCC, 2021). Such spatial uniformity in response suggests that the issue of gender-sensitive climate adaptation is widely acknowledged throughout the study area, reflecting a potentially shared cultural or social understanding of gender roles and their influence on adaptation practices (CARE Rwanda, 2020).

This completes agreement across all spatial locations sampled highlights the importance of integrating gender considerations into climate change adaptation planning at both local and regional scales. The consensus supports the notion that men and women do not only face different climate challenges but also possess distinct knowledge, resources, and adaptive strategies that must be recognized and leveraged (Huyer, 2016b; Pinho-Gomes & Woodward, 2024; Women, 2021). The spatially consistent response implies that policy makers and development practitioners operating in the region should prioritize designing and implementing gender-responsive adaptation interventions that can address the specific needs of both men and women, thereby promoting equitable and effective climate resilience.

Figure 11: **Adaptation Strategy to Flooding by both Men and Women**

Source: Field data (2025).

4.5.7. Women's Needs to Improve their Adaptation Strategies to CC Effects

The distribution of respondents regarding the type of women's needs to effectively adapt to climate change reveals a strong and clear preference for training across the surveyed area. With 75.8% of respondents indicating training as the most critical support, it suggests that women in these communities recognize capacity building such as knowledge on climate-resilient agricultural practices, sustainable resource management, and climate adaptation techniques as fundamental to improving their resilience (CARE Rwanda, 2020; Republic of Rwanda, 2022) . This high demand for training likely reflects geographic patterns where rural and semi-rural women face knowledge gaps that hinder their ability to implement effective adaptation strategies, especially in regions heavily dependent on agriculture and natural resources.

In contrast, financial support ranks second but with a much lower frequency (8.4%), indicating that while monetary assistance is necessary, it may be considered less immediate or accessible compared to training. Decision-making power follows, with 11.6%, highlighting some spatial variation where cultural or institutional barriers may limit women's roles in household or community decisions related to climate actions (Akyala et al., 2023; Awiti, 2022). Lastly, inputs or tools (4.2%) are the least cited, which might reflect localized availability or distribution challenges of physical resources. Overall, the spatial pattern suggests that interventions prioritizing training programs are most relevant and demanded across these regions, but complementary support in financial empowerment and enhancing decision-making roles would also address key gaps in women's adaptive capacity.

Table 16: **Women's Needs to Improve their Adaptation Strategies to CC Effects**

Type of Need	**Frequency**	**%**	**Valid %**	**Cumulative %**
Financial	8	8.4	8.4	**8.4**
Training	72	75.8	75.8	**84.2**
Increased Role in Decision-making	11	11.6	11.6	**95.8**
Inputs/tools	4	4.2	4.2	**100.0**
Total	**95**	**100.0**	**100.0**	

Source: Field data (2025).

Chapter 5: Conclusion and Recommendation

5.1. Conclusion

This study underscored the intensifying climate vulnerabilities faced by smallholder farmers in Bahimba Wetland, where erratic rainfall (92.6%), severe flooding (65.3%), and crop damage (98.9%) are disrupting rural livelihoods. These climate impacts are not experienced uniformly; women, who make up the majority (59%) of the farming population, bear a disproportionate burden due to structural inequalities. Despite owning land at rates comparable to men (92.6%), women lack equal access to critical resources like credit (only 40% have access), climate information (91.6% lack access), and decision-making platforms, which significantly undermines their adaptive capacity. The higher incidence of crop failure and fatalities among female-headed households further illustrates the gendered dimensions of climate risk in the region.

Agricultural systems in Bahimba Wetland are particularly vulnerable, with maize, the primary crop, accounting for the bulk of losses (81.1%). Climatic shifts such as irregular precipitation patterns (1,222–1,276 mm) and slight temperature changes (17.9–18.2°C)—have disrupted farming calendars and heightened reliance on reactive strategies, like adjusting planting dates (83.2%). However, the near-total dependence on agriculture (99% of respondents) and minimal engagement in alternative livelihoods (only 6% report migration) have created a precarious situation where communities lack the flexibility to absorb or recover from climate shocks. Furthermore, the limited external support (only 11.6% received any) and widespread knowledge gaps (83.2%) significantly constrain the development and implementation of robust, forward-looking adaptation strategies.

Finally, the study reveals how demographic factors intersect with climate vulnerability. A large proportion of farmers have low education levels (80% did not progress beyond primary school), which restricts their ability to interpret climate information and adopt innovative practices. Smaller households (1–5 members) face limitations in labor availability for adaptive farming techniques, while larger families often contend with food insecurity. Elderly farmers (aged 66 and above) and women experience layered vulnerabilities due to physical limitations and unequal access to training and support services. These findings highlight the urgent need for integrated, gender-responsive, and socially inclusive adaptation interventions to strengthen the resilience of all smallholder farmers in Bahimba Wetland.

5.2. Recommendations

Based on the findings of this study, a multi-level and gender-responsive approach is essential to effectively build climate resilience among smallholder farmers in Bahimba Wetland. Both local and national governments should prioritize inclusive policy design, livelihood diversification, institutional strengthening, and community-level empowerment. The recommendations are grouped into three core areas:

A. Policy Interventions

To address systemic gender inequalities in climate adaptation, the government should integrate gender-responsive frameworks into national and local climate strategies. This includes conducting gender audits in key policies like Rwanda's Nationally Determined Contributions (NDCs) to assess and correct disparities in the allocation of climate finance, agricultural inputs, and land access. Ensuring women's representation of at least 50% in local climate planning committees will enhance equity and ensure that women's specific needs and perspectives are reflected in adaptation programs.

Moreover, addressing the knowledge gap is critical. The establishment of Community Climate Resource Centers in rural zones like Bahimba Wetland can provide localized weather forecasts, agro-advisories, and training in Kinyarwanda. These centers should prioritize women-led cooperatives in showcasing best practices such as flood-resilient crops (like taro) and improved soil conservation methods. In addition, the development of early warning systems, especially through radio and mobile phone alerts co-designed with women farmers, can enhance real-time response and reduce climate-induced losses.

B. Livelihood Diversification and Resilience Building

To improve resilience, Climate-Smart Agriculture (CSA) practices must be scaled up. This includes encouraging diversified cropping systems, such as integrating aquaculture in flood-prone areas, promoting drought-tolerant legumes (e.g., cowpeas), and expanding agroforestry to stabilize rainfall variability. For small households and women who face labor constraints, there should be widespread access to labour-saving technologies like drip irrigation, raised-bed gardening, and mechanized farm tools.

Financial constraints were identified as a major barrier in this study. Therefore, it is recommended to launch gender-targeted microcredit schemes with low-interest loans tailored for CSA inputs. These should be tied to Village Savings and Loan Associations (VSLAs), accompanied by financial literacy training to empower women economically and enhance their autonomy in making agricultural investment decisions.

C. Institutional and Community Action

Strengthening agricultural extension services is vital for localized and effective support. The government should recruit and train more female extension agents, who can provide gender-sensitive, site-specific advice, especially for wetland-adapted farming practices such as composting, mulching, and raised-bed cropping. Partnerships with NGOs should be leveraged to reach remote and underserved areas through innovations like mobile soil testing clinics or roving agro-advisory teams.

Lastly, enhancing women's empowerment must be central to climate resilience strategies. Government and civil society actors should fund leadership and advocacy programs to build women's capacities for participation in decision-making processes. Legal recognition of customary land rights and the promotion of joint land titling between spouses can provide women with the security needed to invest in long-term adaptation strategies.

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Appendices

Annex 1: **Household Questionnaire Survey**

Questionnaire Number:……………………… Cell/Village……………………………………… Sector………………………………………… District………………………………………		
Section 1: Respondents' Profile		
S/N	Questions	Answers
1	Age	1. 18-30 2. 31-45 3. 46-55 4. 55-65 5. 66 and above
2	Gender/Sex	1. Male 2. Female
3	Marital Status	1. Single 2. Married 3. Divorced 4. Widow 5. Widower 6. Other (specify)………………
4	Family Size	1. 1-5 persons 2. 6-10 persons 3. 11 persons and above
5	Education	1. None 2. Incomplete Primary 3. Primary 4. Incomplete Secondary 5. Secondary 6. TVET/WDA

		7. University 8. Other (specify)…………..
6	Occupation/profession	1. Agriculture 2. Trade/commerce 3. Handcraft 4. Casual job 5. Public servant 6. NGO Employee 7. Other (specify)……………………
7	Migration	1. Migrated 2. Not migrated
Section 2: Climate Change Exposure and Sensitivity		
S/N	Questions	Answers
1	What are the current climatic conditions in this region in terms of temperature patterns compared to the past 30 years?	1. There is a change 2. There is no change
2	What are the current climatic conditions in this region in terms of rainfall patterns compared to the past 30 years?	1. There is a change 2. There is no change
3	If there is a change or variability in terms of temperatures, what are major indicators of that change or variability over the past 30 years?	1. Increase of daily temperature 2. Long dry season 3. Intensification of aridity 4. Other (specify)………..
4	If there is a change or variability in terms of precipitations, what are major indicators of that change or variability over the past 30 years?	1. Erratic and unpredictable rainfall 2. Delay of rainy season 3. Heavy and intensive rains 4. Other (specify)……………
Section 3: Vulnerability to Climate Change Impacts		

1	Which type of climate-induced disaster have been affecting you (or your family) in last five years? (Multiple answers allowed)	1. Flood 2. Landslide 3. Soil erosion 4. Drought 5. Other (specify) 6. None
2	Were those climate-induced disasters frequent?	1. Yes 2. No
3	If yes, what were the losses and damages?	1. Deaths of people 2. Injuries of people 3. Houses destroyed and/or damaged 4. Crops destroyed and/or damaged 5. Infrastructure destroyed and/or damaged 6. Other (specify)…………………….
4	In case of crops destructions and/or damages, did they affect your agricultural production?	1. Yes 2. No
5	If yes, how? (Multiple answers allowed)	1. Crop failure 2. Decreased yields 3. Pest/disease outbreak 4. Soil degradation 5. Food insecurity
	Which crop(s) have been most affected?	1. Maize 2. Irish Potatoes 3. Vegetables 4. Other crops (please specify) ……………………….

	How often do you experience crop failure due to climate factors?	1. Rarely 2. Occasionally 3. Frequently 4. Always
Section 4: Gender, Climate Vulnerability and Rural Livelihoods		
1	In your household, who is primarily responsible for farming related activities?	1. Male 2. Female 3. Both equally
2	Do men and women in your community have equal access to land ownership?	1. Yes 2. No
3	Do men and women in your community have equal access to credit and loans?	1. Yes 2. No
4	Do men and women in your community have equal access to farming inputs (seeds, fertilizer, tools)?	1. Yes 2. No
5	Do men and women in your community have equal access to climate information/training?	1. Yes 2. NO
6	Between men and women, who are more affected by climate change impacts in your community?	1. Men 2. Women 3. Both equal 4. Don't know
7	Do women participate in decision-making on farming activities and adaptation strategies to climate change?	1. Yes 2. No 3. Sometimes
Section 5: **Gendered Adaptation Strategies to reduce CC Impacts**		
1	Have you taken any action to adapt to climate change effects?	1. Yes 2. NO

2	If yes, what strategies have you used? (Multiple options are allowed)	1. Changing planting dates 2. Using improved seed 3. Irrigation 4. Soil conservation 5. Mixed cropping 6. Livelihood diversification 7. Migration 8. Other:
3	What challenges do you face in adapting to climate change effects?	1. Lack of knowledge 2. Lack of finance 3. Lack of land 4. Inadequate support services 5. Gender discrimination 6. Other
4	Have you received any external support from the government and its partners on climate change adaptation?	1. Yes 2. No
5	If yes, what kind of support?	1. Training 2. Materials/inputs 3. Financial 4. Information/extension 5. Other
6	Should adaptation strategies to climate change be designed separately between men and women?	1. Yes 3. No
7	If yes, why?	1. Specify the reason
8	If not, why?	1. Specify the reason
9	What kind of support do women need most to adapt effectively	1. Financial 2. Training

	to climate change?	3. Access to land 4. Decision-making power 5. Inputs/tools 6. Information 7. Other

Annex 2: **Guiding Questions for Interviews**

Interview Guide Number……………………… Names (optional)……………………………….. Position………………………………………. District ………………………………………..	
SN	**Questions**
1	Have you observed any changes in the local climate over the years?
2	How are men and women farmers affected differently by climate change in this community?
3	Are there differences in how men and women cope with or respond to these effects?
4	In your opinion, what cultural or social norms influence how men and women adapt to climate change?
5	What climate change adaptation strategies are currently being used by smallholder farmers in Bahimba?
6	Have any organizations or government programs supported gender-specific adaptation?
7	From your perspective, what kind of adaptation strategies would be most effective for women farmers? Why?
8	How can we ensure both men and women participate equally in designing and implementing climate adaptation plans?