

**CONTRIBUTION OF INDIGENOUS KNOWLEDGE SYSTEMS TO
CLIMATE CHANGE ADAPTATION IN AGRO-PASTORAL REGION OF
NYAGATARE AND GATSIBO DISTRICTS, IN RWANDA**

Théogène HABAKUBAHO

**A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL
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CERTIFICATION

The undersigned certifies that they have read this thesis and hereby recommends for acceptance by the Open University of Tanzania the thesis entitled: **Contribution of indigenous knowledge to climate change adaptation in the agro-pastoral region of Nyagatare and Gatsibo Districts, in Rwanda**, in fulfilment of the requirements for the degree of Doctor of Philosophy in Environmental Studies.

.....

Dr. Josephat Alexander Saria

Supervisor

.....

Date

.....

Prof. Emmanuel Patroba Mhache

Supervisor

.....

Date

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DECLARATION

I, **Théogène HABAKUBAHO**, declare that the work presented in this thesis is original. It has never been presented to any other University or Institution. Where other people's works have been used, references have been provided. It is in this regard that I declare this work as original mine. It is hereby presented in fulfilment of the requirement for the Degree of **Doctor of Philosophy in Environmental Studies**.

A handwritten signature in blue ink, appearing to read 'Théogène Habakubaho', enclosed within a large, loopy circular flourish.

Signature.....

Date: September 16th, 2024

DEDICATION

This thesis is dedicated to my wife, **Béatrice AHIHAGAZE**, my daughters **Aimé Pauline NIRAGIRE** and **Aëla Darlene ISHIMWE**, and my sons, **Evan SHEMA HABAKUBAHO** and **Ethan HIRWA MPANO**, for their endless love, support and encouragement.

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This thesis production resulted from a long consultative and participatory process. The researcher consulted key informants from various institutions including the Ministry of Environment and its agencies, the Ministry of Agriculture and its agencies, high learning institutions, districts and sectors officers and local communities in Nyagatare and Gatsibo Districts. I, therefore, wish to send my appreciation to all persons who provided information included in this thesis. I am also extremely grateful to my supervisors **Dr. Josephat Alexander Saria and Professor Emmanuel Patroba Mhache**, for their invaluable support, guidance, and direction. It is through their diligent guidance that this work ended successfully.

ABSTRACT

The main objective of this research was to assess the contribution of indigenous knowledge in formal adaptation to climate change with reference to the agro-pastoral region of Nyagatare and Gatsibo Districts, in Rwanda. To meet this objective, the research responded to three questions. How does the local community perceive continuing climate changes and associated effects? What is indigenous knowledge developed by agro-pastoralists to cope with changes in climate patterns? What is the contribution of indigenous knowledge to adaptation to climate change in agro-pastoral system in the study area? Under descriptive research, the researcher relied on secondary and primary data collected through questionnaire, focus group discussion, and interviews with key informants. These data were analysed using statistical software such as Excel and SPSS Statistics 28.0.1. Results indicates that 89% of responds perceived a decrease in amount of rainfall as major change while 70% perceive changes in reduction of length of rain season. Reported causes of climate change are dominated by environmental degradation (85.6%), deforestation (57.2%). Perceived effects of climate change on community livelihoods include decline of annual households' income (88.3%), increased incidences of pests and diseases in crops (90.1%). The most predominant indigenous knowledge in predicting weather focus is cloud/sky colour 387(80.6%), change of temperature during the day 319(66.5%), direction and strength of winds 282(58.8%) and lightning and thunder 222(46.3%). Other indigenous knowledge for diseases and pests used by respondents include the use of locally made pesticides 206(42.9%), Burning of pastures and farm residues 198(41.3%), early hand-weeding 297(59.8%), early planting 295(61.5%), use of indigenous medicines 160(33.3%) and selection of indigenous crops and livestock breeds 293 (61.0%). There is evidence of people using indigenous knowledge in adaptation to climate change in the Eastern Province of Rwanda. Despite its limitations and challenges, results of this research indicated that indigenous knowledge can contributes to the adaptation to climate change by complementing scientific knowledge. This is mostly relevant when designing adaptation actions at community and local levels. Thus, this research recommend to formally recognize indigenous knowledge through national policies and strategies and incorporate indigenous knowledge into the design and implementation of adaptation actions.

Keywords: Adaptation, Agro-pastoralism, Climate change, Indigenous knowledge.

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ABBREVIATIONS AND ACRONYMS

AR4	: Fourth Assessment Report
CAADP	: The Comprehensive African Agriculture Development Programme
CAF	: Cancun Adaptation Framework
CV	: Coefficient of Variation
CVI	: Content Validity Index
FAO	: Food and Agriculture Organization
FRW	: Rwandan Francs
ICSU	: International Council for Science
IFAD	: International Fund for Agricultural Development
IK	: Indigenous Knowledge
IPCC	: Intergovernmental Panel on Climate Change
IWRM	: Integrated Water Resources Management
MINAGRI	: Ministry of Agriculture and Animal Resources
MINIRENA	: Ministry of Environment and Natural Resources
MINITERE	: Ministry of Land and Environment
MoE	: Ministry of Environment
NAPA	: The National Adaptation and Programmes of Action
NDC	: Nationally Determined Contributions
NDFFR	: National Dairy Farmers Federation of Rwanda
NISR	: National Institute of Statistics of Rwanda
NST	: National Strategy for Transformation
OUT	: Open University of Tanzania
REMA	: Rwanda Environment Management Authority

RLMUA	: Rwanda Land and Management and Use Authority
RWAF	: Rwanda Water and Forestry Authority
RWB	: Rwanda Water Board
SLT	: Situated Learning Theory
SPAT	: Strategic Plan for the Transformation of Agriculture
SPSS	: Statistical Package for Social Sciences
TAR	: Third Assessment Report
TEK	: Traditional Ecological Knowledge
TK	: Traditional Knowledge
UN	: United Nations
UNEP	: United Nations Environment Programme
UNFCCC	: United Nations Framework Convention on Climate Change
UNESCO	: United Nations Education, Science and Culture Organization
USD	: United States Dollars

CHAPTER ONE

INTRODUCTION

1.1 Background to the Research Problem

In climate change discourse, it has been established that indigenous knowledge developed by indigenous and local communities is a valuable asset for climate change adaptation (Adger et al., 2014). Unfortunately, this knowledge has not been utilized consistently in adaptation efforts and has frequently been overlooked in policy formulation and project design (Adger *et al.* 2014, Jones *et al.*, 2014, IPCC, 2014b).

Recently, indigenous knowledge has attracted attention in climate change discourse, especially in adaptation to climate change for local communities living in agro-pastoral systems. At the global level, indigenous knowledge has been integrated into climate change adaptation discussion and guiding documents. For example, for the first time, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) emphasized the significance of indigenous knowledge. According to this report, indigenous knowledge constitutes a solid foundation for designing adaptation strategies and actions that are essential in helping communities to cope with environmental and climate changes (IPCC, 2007). Furthermore, the IPCC's 32nd session, and a guiding concept for the Cancun Adaptation Framework reaffirmed this significance by including indigenous knowledge in the adaptation concept framework and conclusion of the session (UNFCCC, 2010).

Unfortunately, it has been documented that at national and community levels, different governments and development practitioners are still overlooking indigenous

knowledge and focuses on western knowledge to address climate change shocks and impacts. One of many examples is the introduction of exotic livestock breeds in agro-pastoralism, especially in arid and semi-arid regions. This approach has not yet provided the expected results (Ngigi *et al.*, 2015). The main reason is that the introduction of western knowledge has ignored indigenous knowledge and practices which would have facilitated adaptability and acceptability (Debora, 2018).

Fortunately, in recent years there has been a growing awareness about the role of indigenous knowledge in climate change assessment and adaptation, especially at household and community levels. Recent research indicated that local communities are not passive and, over decades, could understand, predict changes and creatively develop adequate solutions (Jan *et al.*, 2007).

Additionally, local people's opinions, perspectives, behaviors, values, and goals are crucial in addressing and mitigating the effects of climate change (Doss *et al.*, 2001). Local communities, particularly those in isolated and vulnerable environments, have produced a significant body of knowledge on the prevention and management of natural hazards. They use the accumulated knowledge passed down from generation to generation, as well as their experience in observing (Pareek *et al.*, 2011).

In developing countries, especially in Africa, climate change is emerging as the major risk threatening community livelihood based on agriculture and livestock sectors (IFAD, 2008). The effects of climate change on livestock productivity, the incidence of livestock illnesses, and household earnings from livestock production

have all been detrimental (Komba & Muchapondwa, 2012). Furthermore, the agro-pastoral system is harshly affected by changes in rainfall because it caused a shortage in forage, and water resources which are essential in cattle keeping especially in areas prone to prolonged drought (Thompson *et al.*, 2010).

To address effects of climate change, different governments developed adaptation plans to assist the nation and communities in coping with the effects of climate change. In Rwanda, the National Adaptation and Programmes of Action (NAPA), drafted in 2006, was Rwanda's first comprehensive document on climate change. NAPA provides an overview of climate change and its effects on the nation. It focuses on the identification of highly vulnerable sectors, including agriculture, water resources, and energy. This vulnerability is mainly, due to the mutual influences and cumulative effects of floods on steep slopes, desertification trends in agro-bio climate regions of the East and Southeast, the lowering of lake levels and water flows because of pluviometry deficit and prolonged droughts, and deforestation (Government of Rwanda, 2006).

Later, Rwanda ratified and domesticated the Comprehensive African Agriculture Development Programme (CAADP). Key objectives of CAADP were included in agriculture and livestock development policies and policies related to natural resources, poverty eradication and community development. Specifically, the CAADP programme is linked to the implementation of the Strategic Plan for the Transformation of Agriculture (SPAT4), which is a core component of the National Transformation Strategy (MINAGRI, 2018).

Rwanda has also prepared the National Green Growth and Climate Resilience Strategy (MINIRENA, 2011). This strategy is the most comprehensive climate change policy document and focuses on the various strategies and policies that encompass long-term direction in coping with climate change. The strategy was the basis for revising the old environmental policy approved in 2003, which did not include the climate change dimension. The new policy (2019) included proposals to enhance environmental management considering climate variability and change (Ministry of Environment, 2019).

The latest policy document developed by the country is its first Nationally Determined Contributions (NDCs) in 2020. Agriculture, forestry, tourism, water, land use, disaster management, climate data and projections, energy, transportation, industry, and waste are the priority sectors of these NDCs. Nationally Determined Contributions (NDCs) have evaluated the national desire to join global efforts by 2030 to limit global temperature rise to below 2°C by 2100, with a target of 1.5 °C (Government of Rwanda, 2020).

Despite the development of these policy documents, changes in weather events, exceptionally prolonged droughts especially in the Eastern Province of Rwanda, have recently imposed high costs on agro-pastoralists in the region and the country. The eastern part of Rwanda, Specifically the Eastern agro-pastoral region of Nyagatare and Gatsibo districts, has repeatedly experienced a prolonged drought that caused many deaths in cattle and inflation in cattle prices when people tried to cut losses by selling their cattle. Further, the area has experienced food insecurity because some

water planned for rice irrigation on estimated 1,000 hectares of land was released to save cattle (Emmanuel, 2016).

To deal with this ongoing situation, the Government of Rwanda has invested a lot of money in adaptation actions by deploying imported technologies and investing in scientific knowledge and actions. Unfortunately, these investments failed to deliver the expected results, and much money was lost. One of the encountered issues is the lack of ownership and linkage between proposed actions to local characteristics.

Thus, this research sought to assess how indigenous knowledge can complement western knowledge to offer a new adaptation approach. It is the researcher view that, consideration of indigenous knowledge would add value to the design and implementation of formal adaptation strategies especially when it comes to community and households level strategies and actions. The new approach would reduce adaptation costs, guarantee access to adaptation technologies, address real community needs, and increase the acceptability of proposed adaptation actions.

1.2 Statement of the Research Problem

Prolonged and persistent droughts in the Eastern Province of Rwanda resulting from changes in climate, have recently imposed high costs on agro-pastoralists in the region and the country in general. The agro-pastoral region of Nyagatare and Gatsibo districts, specifically Nyagatare and Gatsibo districts, has repeatedly experienced prolonged drought that caused many cattle deaths, inflation in cattle prices as people

tried to cut losses by selling their livestock as well as food insecurity and water shortage.

To address the ongoing situation, the Government of Rwanda has invested heavily in adaptation actions by deploying imported technologies such as construction of valley dams, irrigation infrastructure, and exotic or improved cattle breeds. Unfortunately, these investments did not yield the expected results, leading to significant financial losses. One of the main issues encountered was the lack of ownership and connection between the proposed actions and local characteristics.

In many cases, indigenous knowledge which would have provided local context and contribution to appropriated adaptation strategies were ignored and the proposed adaptation actions were primarily based on scientific knowledge, which are not only costly but also difficult to adopt for ordinary agro-pastoralists. Therefore, this research sought to assess how indigenous knowledge can complement scientific knowledge to offer a new adaptation approach appropriate to local conditions and local communities.

1.3 Objectives of the Study

1.3.1 The general objective of the study

This study's primary objective was to assess indigenous knowledge's contribution to climate change adaptation in the agro-pastoral region of Nyagatare and Gatsibo Districts, in Rwanda.

1.3.2 Specific objectives of the study

- i. To assess local communities' perception of climate changes and associated effects on agro-pastoral region of Nyagatare and Gatsibo Districts, in Rwanda.
- ii. To identify indigenous knowledge developed by agro-pastoralists over time to cope with changes in climate patterns in agro-pastoral region of Nyagatare and Gatsibo Districts, in Rwanda.
- iii. To determine the role of indigenous knowledge in formal adaptation to climate change in agro-pastoral region of Nyagatare and Gatsibo Districts, in Rwanda.

1.4 Research Questions

- i. How does the local community perceive continuing climate changes and associated effects?
- ii. What is indigenous knowledge developed by agro-pastoralists to cope with changes in climate patterns?
- iii. What is the role of indigenous knowledge in formal adaptation process in agro-pastoral region of Rwanda?

1.5 Significance of the Study

This research is meant to contribute to the ongoing efforts in Rwanda and elsewhere in the World to enhance community resilience by exploring approaches to incorporate indigenous knowledge into the formal adaptation process. Understanding indigenous knowledge's contribution to climate change assessment and adaptation will enhance the country's decision-making processes. It is believed that the findings and recommendations of this study are useful for different stakeholders and actors

involved in climate change adaptation including Ministries, government agencies, local authorities, communities and researchers.

For public institutions such as the Ministry of Agriculture (MINAGRI), Ministry of Environment (MoE), Rwanda Environment Management Authority (REMA), Rwanda Water Board (RWB), Rwanda Forestry Agency (RWAFSA), Rwanda Land and Management and Use Authority (RLMUA), Eastern province and districts of Nyagatare and Gatsibo, research findings should be used when designing policies and adaptation strategies. To the agro-pastoralists, the research findings raise awareness of the importance of indigenous knowledge and how this knowledge should be promoted, protected, and integrated into formal adaptation systems. Finally, the study provides a database for other researchers who want to learn and do more about climate change and indigenous knowledge in the region.

1.6 Organization of the Thesis

There are five chapters in this thesis. The backdrop of the research problem, its formulation, the study's goals and objectives, its research questions, its importance, and its organization are all covered in chapter one. Key concept definitions, reviews of the theoretical and empirical literature, policy analyses, research gaps, and conceptual framework are presented in chapter two. The methodology for this study is presented in Chapter three, which covers the research area, research design, research approach, target population, sampling techniques, sampling frame, sample size, data sources, data collection techniques, data analysis, interpretation, and presentation, validity and reliability of research instruments, as well as ethical

considerations. Chapter 4 presents and discusses research findings, while chapter five offers conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature on the study passing through international, regional, and national policies, laws, and strategies related to climate change adaptation and agro-pastoral systems. It also presents definitions of key concepts used in the study, theoretical and empirical literature review, policy review, research gap and conceptual framework.

2.2 Definitions of Key Concepts

2.2.1 Indigenous knowledge

Indigenous knowledge is defined by the International Council for Science (ICSU) as a cumulative collection of information, know-how, practices, and representations preserved and produced by people with extensive histories of environmental interaction (UNESCO/ICSU, 2002). In contrast to the scientific knowledge, commonly referred to as western knowledge or contemporary knowledge, the term "indigenous knowledge" reflects knowledge systems developed by a society (Ajibade, 2003). In many rural communities, local decision-making is based on indigenous knowledge. In this thesis, local communities use indigenous knowledge as practices to cope with stresses imposed by climate changes and transmitted from generation to generation.

2.2.2 Climate change

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified (using statistical tests, for example) by changes in the mean and variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2007). Climate change refers to any temporal change, whether caused by natural variation or human activity (IPCC, 2007). Under the United Nations Framework Convention on Climate Change (UNFCCC), climate change refers to a change in climate that is directly or indirectly attributable to human activity, alters the composition of the global atmosphere, and is in addition to the natural climate variability observed over comparable periods (United Nations, 1992). In the latter definition, there is a distinction between climate changes attributable to human activities altering the atmospheric composition of the earth and climate variability attributable to natural causes. Thus, this research refers to climate change as long-term changes in climate patterns especially rainfall and temperature in the study area.

2.2.3 Climate change variability

Climate variability refers to the fluctuations in the average state and other statistical measures, like standard deviations and the frequency of extreme events, of the climate across various temporal and spatial scales, beyond individual weather occurrences (IPCC, 2018). This variability can stem from natural internal processes within the climate system, known as internal variability, or from natural or human-induced changes in external forces, termed external variability. While climate change pertains to long-term alterations in the climate extending over decades or more,

climate variability encompasses all types of climate fluctuations that persist beyond singular weather events.

2.2.4 Vulnerability to climate change

Vulnerability is the degree to which a system is sensitive to or unable to cope with the detrimental effects of climate change, such as climate variability and extremes (IPCC TAR, 2001). Adger (2006) defines vulnerability as the condition of being susceptible to harm because of exposure to pressures associated with environmental and social change and the inability to adapt. In all definitions of vulnerability, the conclusion is based on exposure and adaptive capacity considerations. It has been established that economically disadvantaged populations are more susceptible to climate-related dangers. This research analyzed the biophysical and socioeconomic vulnerability of communities, as well as their capacity to respond to these hazards.

2.2.5 Adaptation to climate change

The Intergovernmental Panel on Climate Change (IPCC) (2007) defines adaptation as the modification of natural or human systems in response to present or anticipated climatic stimuli or their impacts, which mitigates harm or exploits advantageous opportunities. There are several distinct types of adaptation, such as anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC-TAR, 2001a). Under the United Nations Framework Convention on Climate Change (UNFCCC), adaptation refers to efforts taken in response to climate changes caused by greenhouse gas emissions (UN, 1992). Unlike mitigation, which tackles root causes by reducing greenhouse gas emissions, adaptation

addresses the risks or repercussions of change and variability. IPCC (2001) defines adaptation as all programs or efforts aimed at recouping losses or capitalizing on climate-related possibilities. In a restricted sense, adaptation solely relates to measures conducted at the farm level (IPCC, 2007).

2.2.6 Adaptive capacity

Adaptive capacity, according to IPCC Thematic Annual Report (2001), is a system's ability to adjust to climate change, including climate variability and extremes, mitigate potential damages, take advantage of opportunities, and deal with the resulting effects. Based on this definition, adaptive capacity refers to the actions and strategies that improve a system's ability to respond to various stresses and reduce its susceptibility to climate hazards.

2.2.7 Agro-pastoral systems and livestock systems

Agro-pastoral systems are those livestock systems that, in addition to livestock production, involve some form of crop cultivation (FAO, 1994). Agro-pastoralism integrates crop production and livestock production and is practised amongst settled, nomadic, and transhumant communities (Charles, 2020). In Rwanda, this system is equivalent to extensive grazing whereby cattle are moved on large rangelands. This practice is no longer common in Rwanda with the zero-grazing policy's introduction. Still, it can be observed in the Eastern province due to the availability of large rangelands. In this research, agro-pastoralism referred to livestock production combined with crop production.

2.3 Theoretical Literature Review

This section explored theories behind integrating indigenous knowledge in formal adaptation systems. For this research, the theories opted for include Situated Learning Theory (SLT) and bottom-up versus top-down theories.

2.3.1 Situated Learning Theory

Situated Learning Theory (SLT) was first suggested by Jean Lave and Etienne Wenger in 1991 as a model of learning within a community of practice. SLT is, in simple terms, learning that occurs in the same context as its application. The theory underlying contextual learning is derived from the disciplines of psychology, anthropology, cognitive science, and sociology (Theobald, 2016).

This theory illustrates how learning knowledge within a specific community is part of the socio-cultural context of that community. Thus, acquiring indigenous knowledge involves regular interactions between people, cultures, and environments. Learning indigenous knowledge is mainly informal and occurs on a spontaneous basis. Thus, every community member should be responsible and committed to learning from holders of knowledge to ensure community survival (Tiu, 2007).

This research, SLT was mainly used to define indigenous knowledge developed by agro-pastoralists in Nyagatare and Gatsibo Districts. Further, SLT was used to differentiate scientific knowledge learned from school vis-à-vis the knowledge learned from day-to-day experiences. SLT was also critical to understand challenges

and importance and how indigenous knowledge can be sustained and incorporated into formal adaptation system.

2.3.2 Bottom-up approach versus a top-down approach

In this research, SLT was supported by the theory of bottom-up introduced by psychologist E. J. Gibson in 1966, who took a direct approach to understanding perception (Kendra, 2020). This theory focuses on how vulnerable individuals and communities react to climate variability and how adaptation can improve their resilience (Dessai and Hulme, 2004). Bottom-up approaches tend to focus more on autonomous private adaptation triggered by climate changes; on the contrary, top-down approaches frequently associate planned adaptation.

The scale of adaptation can be at the level of an individual or household but also at the community, regional, national, or even global level including the entire ecosystem. Both approaches have their place in adaptation and complement each other. Actions from the public and private sectors (firms, individuals, households) will be needed to manage the adaptation challenge (Ruth, 2016). This research, both approaches were explored and used to have a broader understanding of the challenges and opportunities of both approaches. This was done with the assumption that indigenous knowledge should not be considered at the expense of western knowledge. Instead, both systems should complement each to offer viable and effective solutions to the alarming situations caused by climate change.

2.4 Empirical Literature Review

2.4.1 Effects of climate change on agro-pastoral systems

According to the IPCC Fifth Assessment Report, the "likely range" of the global average surface temperature increase by the year 2100 is between 0.3 °C and 4.8 °C (IPCC, 2013). Among the potential effects of climate change on livestock are alterations in the production and quality of feed crops and pasture, water availability, animal growth and milk production diseases, reproduction, and biodiversity (Downing *et al.*, 2015). These effects are primarily caused by a rise in temperature, an increase in atmospheric carbon dioxide (CO₂) concentration, alterations in precipitation, and a combination of these factors.

The most important aspects of raising livestock, such as the availability of water, animal productivity, reproduction, and health, are impacted by temperature. Variations in temperature, CO₂, and precipitation all have an impact on forage quantity and quality (Downing *et al.*, 2015). Additionally, the pace of changes brought on by global warming will surpass the potential for spontaneous adaptation by both human populations and animal species (Sarah *et al.*, 2014). In this context, different policy options were formulated by different experts and organizations to increase adaptation in the livestock sector.

Other studies and reports from development organizations demonstrate that livestock products are a crucial agricultural input for ensuring the world's food security because they supply 33% of the world's protein needs and 17% of its calorie needs. Nearly 1.1 billion people are employed in the livestock industry, which supports the

livelihoods of one billion of the world's poorest people. The "livestock revolution" has been coined to describe the quick rise in demand for livestock products in developing nations. It is anticipated that by 2050, global milk production will increase from 664 million tons in 2006 to 1077 million tons, while global meat production will increase from 258 million tons to 458 million tons. It is anticipated that climate change, competition for land and water, and food security at a time when it is most needed will all negatively impact livestock production (Rojas-Downing *et al.* 2015).

Unfortunately, agro-pastoralism has been found to be particularly vulnerable to climate change, despite being the dominant economic model in many rural areas and countries (Busisiwe, 2011). A regional perspective on climate change adaptation has yet to be fully realized, in addition to the fact that the majority of NAPAs are usually seen as having been insufficiently conceived and implemented (Mubaya, 2014).

Production of cattle is constrained by a lack of animal food. Poor health, an environment with unresponsive policy, the depletion of natural resources, rural poverty among livestock keepers, pests and diseases that increase animal morbidity and mortality, droughts and floods, or disease epidemics linked to climate change, a high level of livestock exposure to climatic variability, and erratic nature are just a few of the problems that rural livestock keepers must contend with (Busisiwe, 2011).

Changes in agro-pastoral practices may include (i) the diversification, intensification, and integration of pasture management, livestock, and crop

production; (ii) the modification of land use and planning; (iii) the modification of the timing of operations; (iv) the conservation of nature and ecosystems; and (v) the introduction of mixed livestock farming systems, such as stall-fed systems and pasture grazing. Nonetheless, developing nations are typically characterized by a lack of technology in livestock breeding and agricultural programs that could aid in accelerating adaptation (Goncalves *et al.*, 2015).

In the East African region, National Adaptation Program of Action (NAPA) documents for Tanzania, Uganda, Rwanda, and Burundi have identified a number of adaptation-supporting priority sectors. The effects of climate change on livestock productivity, livestock disease incidence, and household earnings from livestock production are all detrimental (Mubaya, 2014).

Literature review indicates that only few research was conducted in Rwanda on the effects of climate change on agro-pastoral systems. Few articles reviewed suggest that climate change is now widely recognized as a fact, and there is growing evidence that climate change poses a threat to the development process (NBDF, 2015). All models and emission scenarios project increases in average temperatures, while most models also indicate increases in annual precipitation totals, albeit a few indicate small decreases (Rugigana *et al.*, 2016). Total rainfall for the two rainy seasons is projected to increase; heavy rainfall events are less certain, although it is very difficult to make local-scale climate projections with the current level of knowledge (NBDF, 2015).

The Ministry of Disaster Management in Rwanda (MIDIMAR) found that the country is highly prone to drought, landslides, flooding, earthquakes, and windstorms. The districts of Kayonza, Gatsibo, Kirehe, Nyagatare, Rwamagana, Ngoma, and Bugesera in the eastern province are moderately to extremely vulnerable to severe drought, according to an assessment of drought risk. The slope susceptibility of the modern, southern, and northern provinces of the Congo-Nile Ridge ranges from moderate to extremely high (MIDIMAR, 2015)

In the other hand, based on a 25-year return period, the flood hazard assessment found that locations surrounding the five examined catchments Nyabarongo, Sebeya, Nyabisindu, Mukungwa, and Kagitumba are susceptible to flooding. In addition, historical data on flood episodes revealed that flood dangers are likely to occur in numerous sites around the nation. Due to data constraints, only catchment analysis was possible for this study (MIDIMAR, 2015).

2.4.2 Indigenous knowledge in climate adaptation

Indigenous knowledge has been described by many researchers (Hiwasaki et al., 2014; Egan, 2013) as a complex and cumulative body of information that has been preserved and developed by groups of people who have long histories of interacting with the environment. Nakashima et al. (2012) claim that this indigenous knowledge is easily accessible to farmers in rural areas, reasonably priced, and a climatically creative tool for controlling climate unpredictability. The term "indigenous and local knowledge" is referred to by several titles, including Traditional Knowledge (TK), Traditional Ecological Knowledge (TEK), and simply Indigenous Knowledge (IK),

according to the World Bank (2006). All definitions share the fact that indigenous or local knowledge is specific to a particular culture, community, and area, though.

Indigenous knowledge was emphasized as a valuable resource in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) for developing adaptation and resource management strategies in response to environmental and other types of change. Indigenous knowledge was included as a guiding principle in the Cancun Adaptation Framework (CAF), which was approved by Parties to the United Nations Framework Convention on Climate Change in 2010. This acknowledgment was reaffirmed during the IPCC's 32nd Session (IPCC, 2010a) (Nakashima et al., 2012).

To meet the new challenges brought on by climate change globally, decision-makers must develop policies and formulate plans of action based on the greatest information currently available. Our knowledge of how social and earth system interact is significantly improved by the bio-physical and social sciences. But there has been a growing consensus in recent years that the climate calamity cannot be remedied solely by scientific knowledge. Indigenous knowledge also known as traditional knowledge, is increasingly recognized as being a key source for comprehending climate change and creating adaptation strategies (Mafongoya and Ajayi, 2017).

Local populations have been shown in studies to be essential and active components of many ecosystems, and they may even contribute to increase these ecosystems'

resilience (Salick and Anja, 2007). The local community's reliance on natural resources, which are immediately impacted by changes in climatic patterns, justifies this. Most of these communities live in remote areas with fragile ecosystems with low income. These challenging conditions have forced them to develop practices and expertise that help them interpret and counter climate change impacts creatively. This knowledge is acquired and transmitted from generation to generation.

According to a survey of literature, agro-pastoralists have developed native adaptations to diverse environmental and climatic changes by relying on their in-depth understanding of their local environment. Some coping mechanisms, however, have proven ineffectual due to the growing human population, urbanization, environmental deterioration, and increased animal resource demand. In addition, it's possible that the pace of changes brought on by global warming will be faster than the ability for spontaneous adaptation of both human societies and animal species (Gonçalves *et al.*, 2015). Livestock adaptation tactics consider not just their tolerance to heat but also their capacity to endure, thrive, and procreate in the presence of malnutrition, parasites, and illnesses (Gonçalves *et al.*, 2015).

These steps could involve identifying and supporting regional breeds that have developed resistance to local environmental stressors and feed sources, and (ii) enhancing regional genetics through breeding with breeds that can withstand heat and disease (IFAD,2018). The likelihood that the new breed will survive and be able to adapt is higher if climatic change occurs more quickly than natural selection. Further, the promotion of interregional trade and credit programs, for instance,

could improve the farm market (Indian Association of Hill Farming, 2017).

2.4.3 Role of indigenous knowledge in climate change adaptation

In reaction to present or anticipated climatic stimuli and their impacts, natural and human systems must be adjusted as part of climate change adaptation (Busisiwe, 2011). The literature offers a variety of adaptable strategies, including reactive, anticipatory, autonomous, and planned adaptation. Reactive adaptation refers to decisions made by organizations, people, plants, and animals after the fact (Busisiwe, 2011). In this scenario, adaptation measures are taken to address the situation that has happened all is happening.

On the one hand, the literature review indicates that most adaptations are drawn from scientific knowledge and are formulated in policy actions. Production adjustments, which include diversification, intensification, integration, pasture management, livestock, and crop production, modifying land use and irrigation, adjusting the time of activities, and ecosystem conservation, are the first available choice for policy. This entails adjusting stock distances and routings as well as implementing mixed livestock farming methods (Tadesse and Dereje, 2018).

Market measures, such as enhancing the farm market, boosting inter-regional commerce, and implementing credit schemes, constitute a second policy alternative (Indian Association of Hill Farming, 2017). Important institutional and policy changes include the elimination or implementation of subsidies, insurance systems, and income diversification practices, as well as the implementation of Livestock

Early Warning Systems, as with IFAD-supported interventions in Ethiopia, and other forecasting and crisis preparedness systems (Tadesse and Dereje, 2018).

For the above alternative to be successful, it must be backed by agro-pastoralists with heightened awareness of global and local developments. The enhanced capacity of herders and livestock producers to comprehend and adapt to climate change. Training in agro-ecological technologies and practices for producing and preserving forage increases the availability of animal feed, hence decreasing hunger and mortality in herds (Tadesse and Dereje, 2018).

Finally, livestock management systems with efficient and cost-effective adaptation strategies must be designed for rural poor with limited adaptive potential (LMS, 2013). This includes the provision of shade and water to alleviate heat stress caused by rising temperatures, as well as a reduction in the number of cattle, as a smaller number of more productive animals will result in more efficient output and fewer greenhouse gas emissions from livestock production (Sarah *et al.*, 2014).

On the other hand, it has been established that indigenous knowledge is a significant resource in climate change, particularly in agro-pastoral systems that rely on natural resources. This is justified by the fact that the land and natural resources used in agro-pastoralism are inseparably linked to agro-pastoralists identities, cultures, livelihoods, and physical and spiritual well-being.

Indigenous and local knowledge has been regarded as the key strategy for climate change adaptation, especially in Africa and other developing nations (Tadesse and Dereje, 2018). More than 30 percent of the world's indigenous languages are spoken in Africa, and they are extremely rich in ecosystem-specific information regarding biodiversity, soil systems, and water. Indigenous knowledge informs crucial life decisions in Africa, from day-to-day subsistence activities to long-term projects (Leal Filho *et al.*, 2021).

Moreover, indigenous knowledge is an intrinsic part of the socio-cultural system, which includes location, language, categorization systems, resource use practices, social interactions, religion, belief, values, rituals, and spirituality. Therefore, indigenous knowledge is an indispensable and dynamic resource for the survival of agro-pastoralists and other local people. This knowledge is also a cornerstone of social, cultural, political, economic, scientific, and technical identity (Magni, 2017; Ayal *et al.*, 2015), which can help achieve sustainable development goals (Tengo *et al.*, 2014).

Although agro-pastoralist communities around the world are negatively impacted by climate change and climatic extremes, many traditional civilizations, particularly those that depend on rain fed agriculture and cattle, have specific demands. In these circumstances, indigenous knowledge is known for its ability to play a significant role in resource governance, conservation, and sustainable use of biodiversity and ecosystems, as well as climate change adaptation (IPCC, 2022; IPCC, 2021; Niang *et al.*, 2014). (IPBES, 2018 & 2012; Tengo *et al.*, 2014).

Indigenous weather and climate knowledge in Africa has been incredibly effective in reducing the negative effects of climate change (Nyadze *et al.*, 2021; Adger *et al.*, 2014). In other cases, indigenous peoples serve as the model for actions that help communities cope with the hazards of climate change and survive. The basis of both traditional and modern scientific weather and climate forecasting systems is observations, experiments, and validations. While modern weather forecasting uses the arithmetic mean of climate variables, indigenous meteorological forecasting only considers the observation of short-term climate extremes. The supply of blended prediction services could help in giving more accurate information, yet this forecasting knowledge has limitations (Radeny *et al.*, 2019). Despite this, there is a strong understanding of climate change that takes local perspectives into account when making an assessment. This contributes to the study of the relationships between people and places as well as the development, transmission, and evolution of local knowledge over time (Adger *et al.*, 2014).

2.4.4 Status of Indigenous knowledge in national climate change and adaptation

Policies

In Rwanda, the only documents that are related to climate change, in general, are mainly policy documents. These policy documents include Vision 2050 Aspirations. Vision 2050 aspires to take Rwanda beyond high income to high living standards. Its income targets are to attain upper middle-income country status by 2035 and high-income status by 2050 with an objective of providing high-quality livelihoods and living standards.

Climate change considerations are integrated into essential priority areas, including going beyond basic needs to secure a high standard of living. This includes a focus on sustained food security and quality nutrition, modern housing and settlements in environmentally-friendly and climate-resilient areas, access to affordable, reliable, and clean energy, and the modernization of cities, towns, and rural settlements with smart, green initiatives, alongside well-designed transport facilities and efficient public and private services.

In the short term, the country developed National Strategy for Transformation (NST1) In the medium term, the National Strategy for Transformation, NST1/Seven Years Government Program (2017-2024) sets the priority for a green economy approach in its Economic Transformation pillar that promotes “Sustainable Management of Natural Resources and Environment to Transition Rwanda towards a Green Economy”. Moreover, environment and climate change were highlighted in NST1 as cross-cutting areas of policy concern which can be positively impacted by a range of development activities with priority given to agriculture, urbanisation, industries and energy.

Another important policy document developed in effort to address climate hardship is the Green Growth and Climate Resilience Strategy (GGCRS). The strategy has been developed with a vision in mind for Rwanda to be a developed climate-resilient and low-carbon economy by 2050. The 14 programmes of action include diversifying energy sources with low-carbon energy grid and promoting green technology and resource-efficient industries throughout all production levels from

the primary stages such as agricultural production and mining to manufacturing industries in the secondary to tertiary public and private sector industrial activities as well as transport and urban development.

The most recent policy document is the Nationally Determined Contributions (NDCs) Rwanda's NDC which is built on the Green Growth and Climate Resilience Strategy (GGCRS) and focuses on adaptation and mitigation. The key sectors identified and prioritised under NDCs include agriculture, forestry, tourism, water, land use, disaster management, climate data and projections, energy, transport, industry and waste. The NDC for Rwanda reflect the national ambition by 2030 to join global efforts toward curbing global temperature rise below 2°C by 2100, with an aspirational target of 1.5°C.

Unfortunately, none of the above policy documents has considered indigenous knowledge to address climate adaptation. To tackle environmental degradation and climate change, policy documents are relying on western technologies. In terms of agro-pastoralism, attempts are made to improve native breeds by introducing and interbreeding with foreign species (MINAGRI, 2017).

2.5 Research Gap

The literature assessment revealed a lack of clear and systematic understanding of the effects of climate change and variability on Rwanda's diverse agro-ecological zones and the contribution of indigenous knowledge to the creation of appropriate adaptation solutions. During the literature assessment, few scientific and academic

research documents covering climate change's broad elements were uncovered. These include the prediction of East Africa's short rains based on sea-surface temperature and atmosphere coupling (Mutai *et al.*, 1998), the impact of climate change and climate variability on the altitudinal ranging movement of mountain Gorillas in Volcanoes National Park in Rwanda (Musana *et al.*, 2011), and investigating climate change vulnerability and planning for adaptation: Learning from a study of climate change impacts on the Mountain Gorilla in the Albertine Rift (McGahey *et al.*, 2013).

None of the studies have evaluated and documented the impact of indigenous knowledge to climate change adaptation in Rwanda. This suggests that additional research is required to examine existing livestock systems in order to determine the impact of climate change in each agroecological zone and to evaluate how traditional farmers have adapted to a changing environment and climate. This includes recognizing and documenting indigenous knowledge systems as acknowledged by the Intergovernmental Panel on Climate Change in climate adaptation strategies (IPCC, 2010). Consequently, this research is part of an attempt to discover and document indigenous knowledge and to suggest indigenous knowledge that might contribute to ongoing efforts to design and execute effective and suitable community-based climate adaptation solutions.

2.7 Conceptual Framework

Literature reveals that climate change exists, and communities worldwide are experiencing its impacts. Due to the rural community's location in vulnerable

ecosystems, such as drought-prone areas, desert, and marginal land, among others, the effects of rising average temperature, rainfall variability, and an increase in the frequency and severity of droughts are anticipated to be both rapid and severe. Indeed, climate change directly threatens many rural communities, including agro-pastoral systems, their dependence on resource-based livelihoods. Rural populations in agro-pastoral systems are the most susceptible to the consequences of climate change due to their dependence on resources and the environment and their marginalization from decision-making processes. However, they are neither inactive nor without resources; they actively interact with their natural environment in their daily existence. They are also seasoned and perceptive observers who have amassed substantial and refined bodies of information and practices regarding their background, its variability and evolution. Figure 2.1 presents a conceptual framework that was used to meet the objective of this research and to respond to research questions.

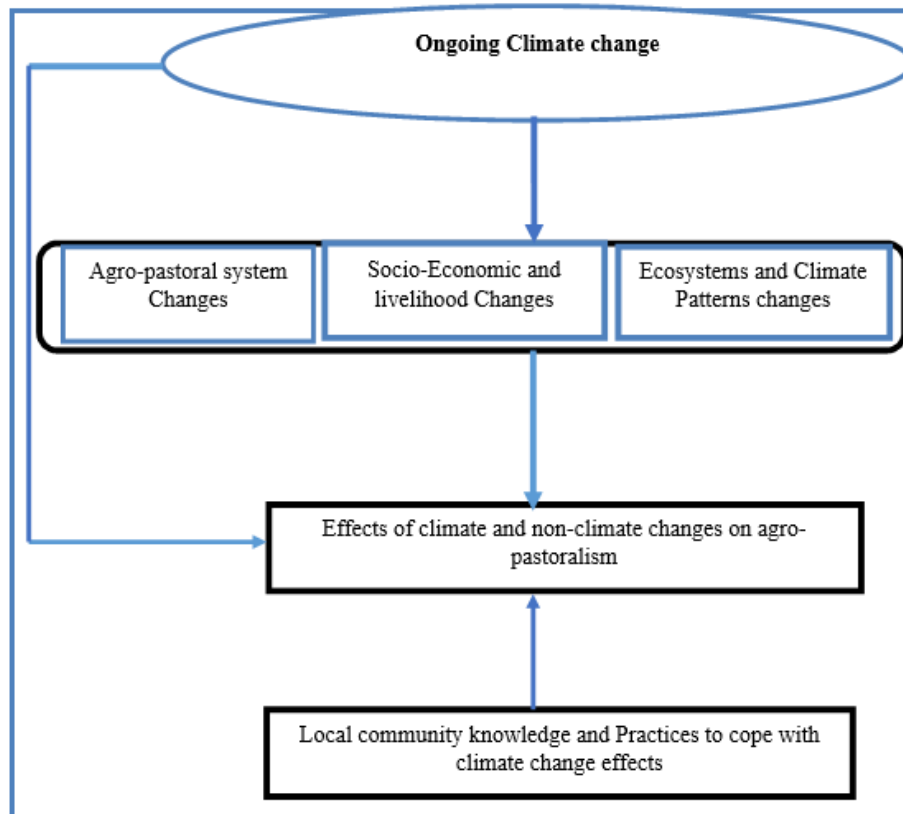


Figure 2.1: Conceptual framework for the study

Source: Adapted from, Karki et al., 2017.

The proposed conceptual framework in the above Figure 2.1, portrays different ongoing changes (climatic and non-climatic), which have been translated to further changes, including agricultural, economic, sociocultural, and environmental resources. On-going changes are causing different community hazards intersect with climate risks to produce impacts. In such a situation, the most affected local communities, especially those who depend on agriculture and livestock and rely on natural resources for their livelihoods. These effects are exacerbated when these communities experience high vulnerability with low adaptive capacity. Therefore, understanding the climate risks of a certain community plays an important role in how climate change is perceived at the local level (Granderson, 2014).

As documented earlier, the communities affected by climate and non-climate are not passive and have historically tried to cope with changing environment. That is why the researcher attempted to identify and document indigenous knowledge used by local communities to adapt to climate change effects. In addition, this knowledge is assessed in terms of challenges related to their relevance in current adaptation systems and their importance in climate change adaptation. This helped me understand the role of indigenous knowledge in formal adaptation strategies and actions.

With the aggressive intrusion of western knowledge, limitations of indigenous knowledge and the appearance of new climate change threats, indigenous knowledge cannot resolve the current stresses. On the other side, western knowledge promoted by different government agencies and other actors also has its own limitation, especially in community-based adaptation. Thus, it is believed that a combination of both indigenous knowledge and western knowledge may constitute a better way of addressing climate-induced risks and climate.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The target population, research methods, study area, and design are presented in this chapter. Additionally, it covers sampling processes and design, data gathering techniques, data processing and analysis, validity and dependability of research tools, and ethical concerns.

3.2 The Study Area

This study was conducted in Nyagatare and Gatsibo Districts, formerly Umutara Region. These two districts are in the Eastern Province of Rwanda towards the Tanzania and Uganda borders (Figure 3.1). A big part of these districts was opened to human settlement in 1996 from the degazetted lands of the Akagera National Park. Since then, both districts have experienced a major influx of returning refugees and their livestock from neighboring countries and migrants from other provinces in Rwanda.

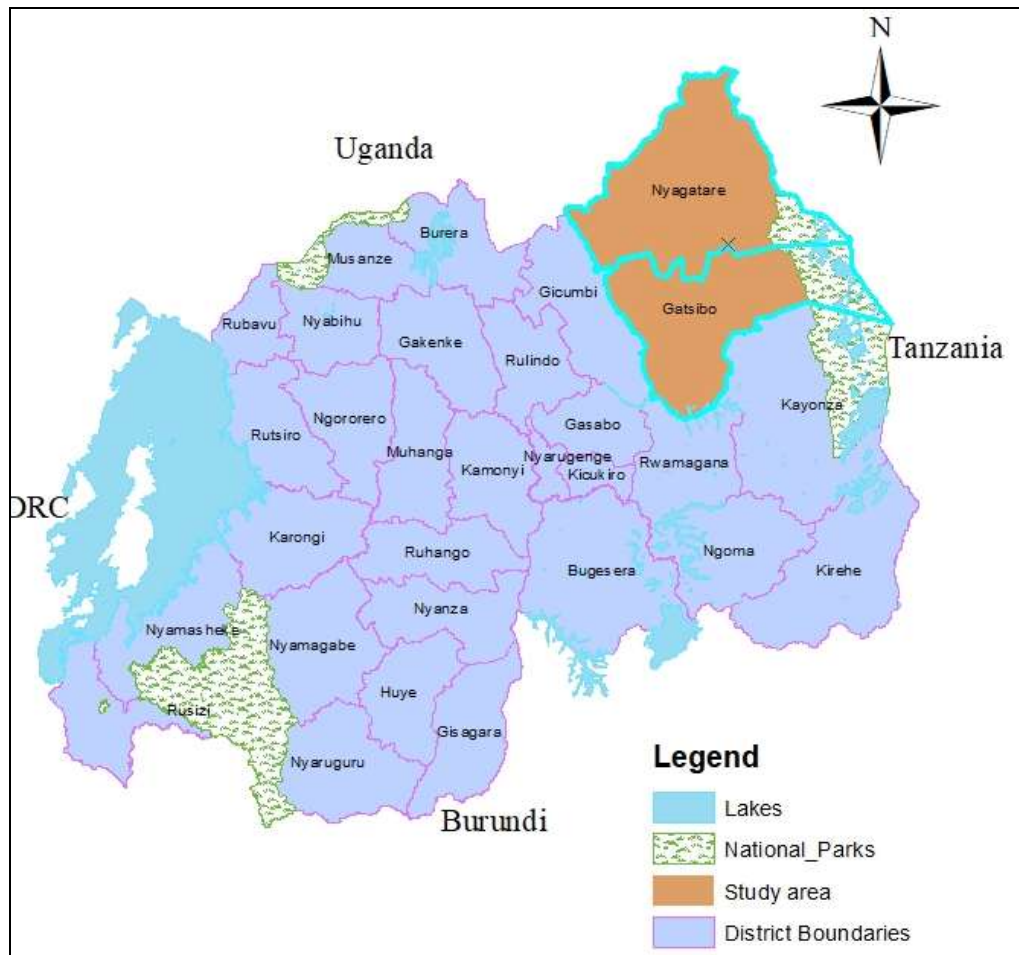


Figure 3.1: Location of study area on the administrative map of Rwanda

Source: Prepared by author-based National base map, 2021

The Study area is characterised by low hills that are common in the eastern lowlands of Rwanda, as well as grassy plains. The low hills mostly contain savanna vegetation, while dense forest patches are restricted to riverbanks. The Muvumba river and Akagera National Park are the main natural ecosystems found in the area.

The mean annual precipitation in the study area is 808 mm (Ministry of environment, 2018). The two rainy seasons from March–May and September–December receive a total rainfall of ~310 mm and ~354 mm respectively. Between 1981–2017, there has been a decreasing trend in rainfall amounts in the first wet season (March–May) and

an increasing trend in rainfall for the second wet season (September–December). For annual rainfall between 1961 and 2018, the period between 1991 and 2000 has been the driest. These observations showed a marked rainfall deficit in 1992, 1993, 1996, 1999 and 2000 with rainfall excesses in 1998 and 2001.

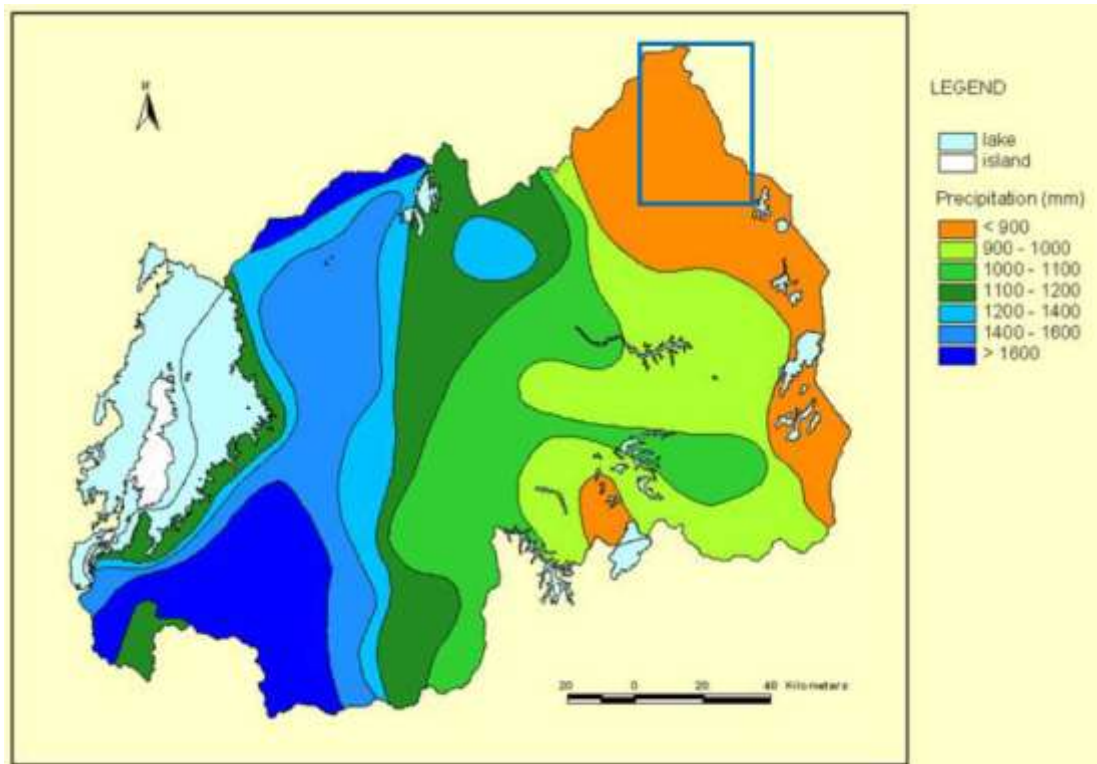


Figure 3.2: Distribution of Annual rainfall in Rwanda

Source: Rwanda Meteorology Agency, 2020.

The first dry season occurs from late May to early September, with the dry season months prolonged in the lower altitude areas and towards the east. As the altitude of the area is lower than the rest of the country, the average temperature of 21°C is higher than averages in most other regions of the country (Ministry of Environment, 2018). Temperature observation data indicates an average maximum temperature of

24°C and average minimum temperature of 14°C (Rwanda Meteorology agency, 2020).

The region is susceptible to drought, experiencing frequent rainfall deficits, delayed rainfall starts, early cessations, and numerous dry spells. Droughts in this area are often prolonged, recurrent, and can be persistent. They frequently result in famine, food scarcity, a reduction in flora and fauna, and the displacement of people due to insufficient pasture and food. Data from the Lake Ihema meteorological station, spanning from 1980 to 2017, indicates an increase in extreme weather events, characterized by extended dry periods and higher peaks of precipitation during the rainy seasons.

Furthermore, Nyagatare and Gatsibo district features a sparse hydrographic network. Apart from the River Muvumba, which crosses traverses the district, and the Akagera and Umuyanja Rivers that delineate the borders with Tanzania and Uganda, there are no significant rivers for local use. Other minor rivers in the study area include Nyiragahaya, Kayihenda, Karuruma, Nayagasharara, and Kaborogota. The Akagera River marks the boundary with Tanzania, and the district's eastern part falls within the Akagera National Park. The limited hydrographic network not only hinders timely irrigation but also presents a considerable challenge in fulfilling the water requirements of both humans and animals' consumption (Government of Rwanda, 2018).

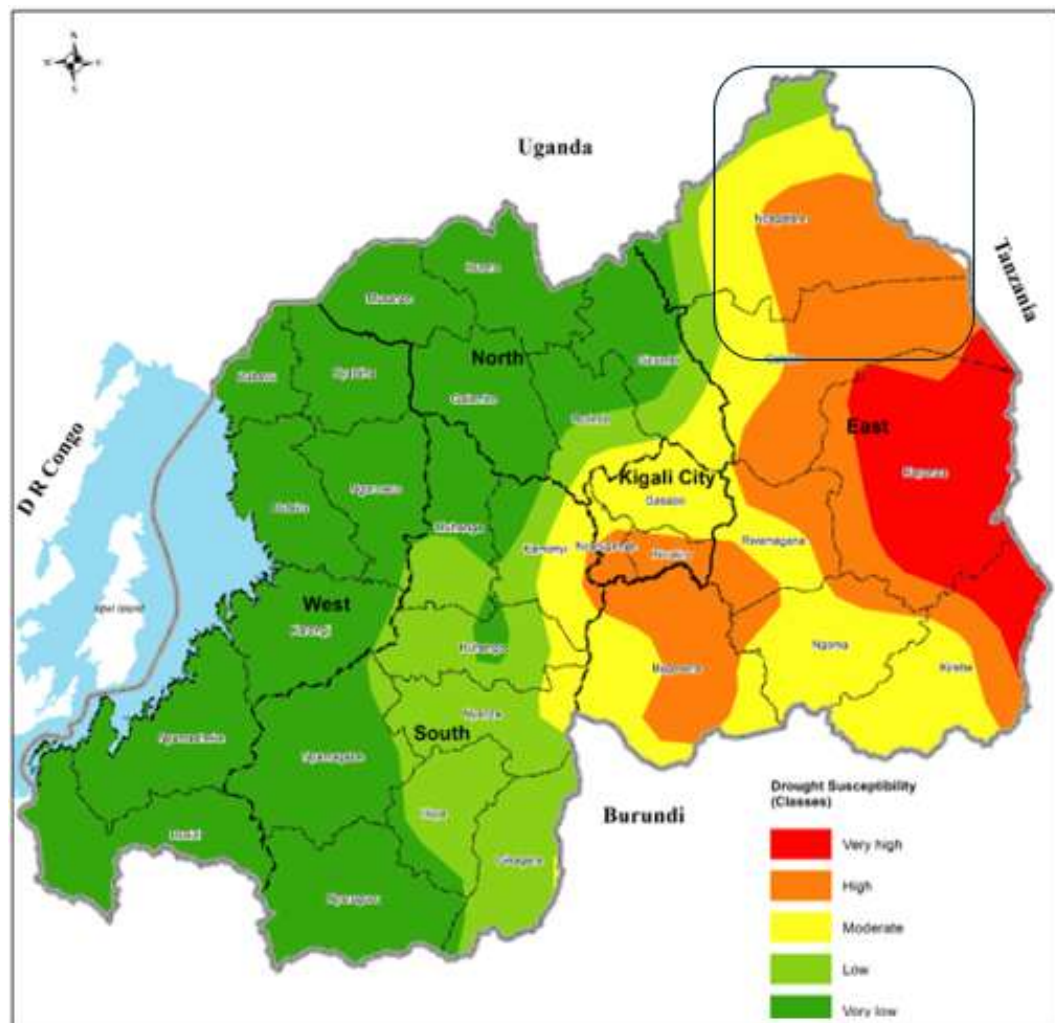


Figure 3.3: Location of the study area in drought susceptibility in Rwanda

Source: National disaster atlas, MIDMAR, 2018

According to historical records between 1961 and 2018, the years 1991 to 2000 were the driest since 1961. Furthermore, rainfall was significantly deficient in 1992, 1993, 1996, 1999, and 2000, while there were excesses in 1998 and 2001. (MIDMAR, 2015). This has also affected natural resources whereby drought has forced herders to move their herds from their pastures closer to or into the Akagera National Park during the dry season (Ministry of Environment, 2018).

The plant diversity in the study area is characteristic of lowland savanna vegetation (i.e. it is a tree-grass mosaic). Apart from crops dominated by large-scale rice cultivations in the wetlands and bean, maize and banana on the hills, natural vegetation consists predominantly of *Vachellia* (formerly the genus *Acacia*) tree species. The dominant grasses of the savannas are red oat grass (*Themeda triandra*) and various thatching grass species (including *Hyparrhenia filipendula*). In the southeastern part of the Nyagatare District, the Akagera National Park conserves a savanna-forest ecosystem. The park hosts a high diversity of plants, including many threatened species such as *Blighia unijugata* (*Umuturamugina* in the local language), African sandalwood (*Osyris lanceolata*, locally known as *Kabaruka*), Gummy canthium (*Afrocanthium lactescens*, locally known as *Umukindo*) and knob wood (*Zanthoxylum chalybeum*, also known as *Intareyirungu*). The invasive *Lantana camara* is also prevalent throughout the savannas in the district and has attributed to changing land use (Wronski et al., 2017).

Furthermore, the wetlands of the Nyagatare and Gatsibo districts are dominated by *Cyperus papyrus* and *Cyperus latifolius* (Ministry of environment, 2018). Numerous alien ruderal/plant species that favour disturbed areas were identified in the study area including timber trees such as silk oak (*Grevillea robusta*, locally known as *Gereveriya*) and *Eucalyptus* sp., shrubs such as *Senna spectabilis* (*Gasiya*) and fruit trees such as *Mangifera indica* (*Imyembe*) and *Persea americana* (*Avoka*). The same document identified indigenous tree species that included species of the genera *Vachellia*, *Euphorbia* and *Ficus*.

According to the agro-climatic zones, the study area is located in as Eastern agro-pastoral zone and Eastern semi-arid agro-pastoral zone(Figure 3.4) where pastoralism is the primary source of income.

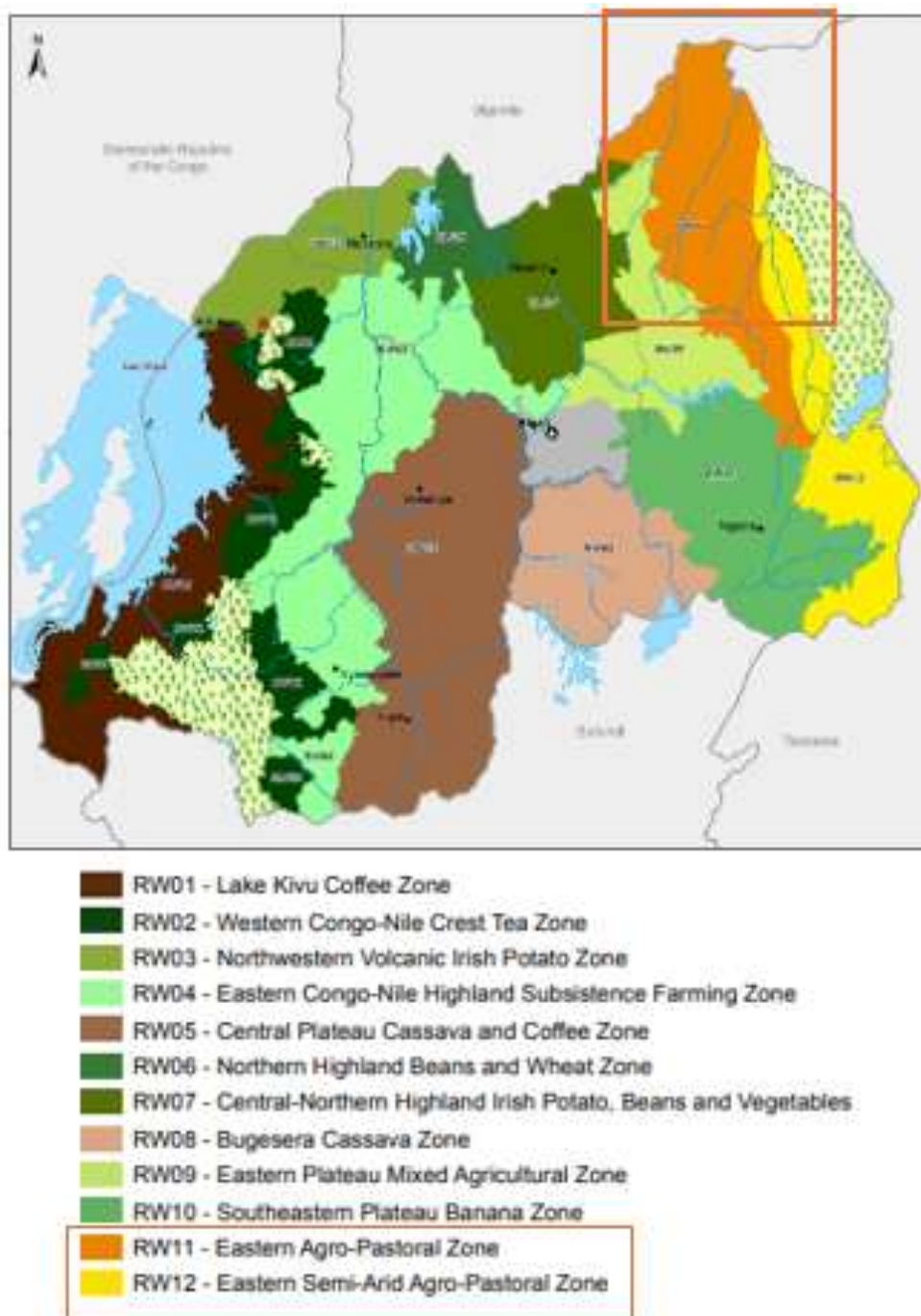


Figure 3.4: Location of the study area in the agro-climate zone of Rwanda

Source: USAID and FEWS NET, 2015

The primary livelihood activities in the study area agro-pastoralism and the area host native cattle breeds like the Ankole, along with their crossbreeds with exotic varieties. Local farmers prefer these breeds for their resilience to climatic extremes and limited fodder availability. Moreover, water availability is considered a critical constraint to livestock production growth in the Nyagatare and Gatsibo districts. Traditional breeds in the region are typically capable of traveling extensive distances daily to find grazing lands and water. While exotic livestock breeds introduced to the area post-1994 genocide, yield more meat and milk than traditional ones, they are more susceptible to traveling long distances for water. Consequently, the district's rural development strategy has included investments in enhanced rainwater storage and groundwater-fed dams (Karamage et al., 2016).

From demographics, with a total population of 466,000 people, the Nyagatare District is the second most populous district in Rwanda (MoE, 2017). Approximately 49% of the population is male, and ~51% is female. Approximately 44% of the district live in poverty, of which ~20% live in extreme poverty. Like other parts of Rwanda, the primary livelihood strategies in the study area are predominantly focussed on agriculture.

Most of the land in the eastern savannas serve as rangelands for the grazing of livestock, particularly cattle and goats. Deforestation caused by the creation of new grazing areas — combined with subsequent overgrazing, drought and wind erosion — has resulted in severe landscape-level degradation of lowlands and savannas. This has led to a limited availability of forage for livestock (which further compounds

overgrazing and exacerbates deforestation), and large-scale soil loss which decreases the productive potential of the land. Crop farming is therefore also a livelihood type used in the savannas to support livestock farming. The crop types grown in the Nyagatare district include, *inter alia*, wheat (35% of the total crops produced), beans (13%), bananas (13%), cassava (11%), sorghum (9%), soybeans (6%) and rice (2%) (MINAGRI, 2013). In addition to agriculture, people in Nyagatare district are also active in rice and maize processing, as well as in the production of local wine types (Government of Rwanda, 2018).

Approximately 29% of households in Nyagatare and Gatsibo Districts own agricultural lands that are smaller than 0.3 ha. In the eastern savannas, some households have rangelands larger than 25 ha. However, given the extent of degradation, as well as extended and more intense drought conditions resulting from climate change, even these larger rangelands are considered insufficient in size for sustainable livestock farming. Only ~42% of the population in the Nyagatare and Gatsibo Districts has access to clean drinking water (Minagri, 2013), while 20% has no access to both clean drinking water and sanitation (Dusabe et al., 2019). Located in a semi-arid zone, Nyagatare and Gatsibo experiences issues with water availability. Most households in the district utilise surface water (rivers or valley dam water) and public standpipes.

3.3 Research Design

Research design, according to MacMillan and Schumacher (2001), is a strategy for choosing participants, research locations, and data collection techniques to address the research topic (s). Polit and Beck (2004) and Wood and Haber (1998) said that choosing an effective research design should be influenced by a key factor, namely whether the design does the greatest job of producing reliable responses to the research question.

The researcher chose a descriptive research design for the current investigation. The descriptive design was preferred for its high representative, and it is simple for the researcher to get the participants' thoughts (Polit and Beck, 2004). Additionally, descriptive research provides characteristics of what is there in terms of variables or conditions in a situation and to learn more about the status of the phenomenon (Ticharwa, 2014).

3.4 Research Approaches

Research is not neutral but reflects various interests, values, abilities, assumptions, aims and ambitions. This study used a mixed research approach combining both qualitative and quantitative research approaches. To enhance the quality and validity of empirical research, triangulation refers not only to the employment of various research methodologies but, more specifically, to the mixing of complementary methods of data collecting and theory development (Etzold, 2012). For qualitative data collection, interviews with professionals, community leaders and selected elders were used. This information was complemented with focus

group discussions which involved cooperative leaders and chosen members of the community. Under quantitative research, a household questionnaire was administered to sampled agro-pastoralists in the study area.

3.5 Targeted Population

This research targeted agro-pastoralists in Nyagatare and Gatsibo District (Table 3.1). Agro-pastoralists in the area were obtained from the 4th National Census of Population and Habitat (NISR, 2012), and the total number of households in the two administrative districts were considered. The target population was 65,402 households, including 33,717 households in Nyagatare District and 30,822 households in Gatsibo District. The population appears to be large, so the researcher has used sampling methods and techniques to get a small population size (Table 3.1).

Table 3.1: Target Population

Category of targeted Population	Size of the Population		Total
	Nyagatare	Gatsibo	
Total Households	33,717	30,822	64,539
Grand Total	33,717	30,822	64,539

Source: NISR, 2018

3.6 Sampling Procedures

A sample is a group of comparatively fewer persons picked from a population for the purposes of research (Alvi, 2016). It is also the choosing of a portion of an aggregate or total based on a conclusion or inference (Bernard, 2006). In other words, it is the

process of acquiring knowledge about an entire population by analysing a small sample. This study included two sampling methods: systematic random sampling and purposive sampling.

3.6.1 Systematic random sampling

Systematic random sampling was used to sample villages where households (with cattle) were sampled from Nyagatare and Gatsibo District. In total, 40 villages were sampled from 1,230 villages by using an interval of 31($(N/n=1,230/40=30.75\approx 31)$). Thus, on a list sorted A-Z district by district, 40 villages were selected, starting from randomly selected villages and skipping 31 to choose the next village and so on, up to a total of 40 villages. Each village was represented by total sampled households divided by 40 villages ($480/40$) to get 12 households per sampled village. Once villages were known, households were selected with simple random selection whereby all households in the village were listed, and 12 households were selected randomly applying the same interval.

3.6.2 Purposive sampling

The main goal of purposive sampling is to focus on the population of interest able to answer research questions. Given that this research aimed to collect information related to climate change and agro-pastoralism, only agro-pastoralists were purposively targeted. The same individuals dealing with environment and climate change, agriculture, natural resources and livestock from planning, research and technical was selected. Thus, at the district level, officers dealing with subject matter, including agronomist, veterinary officer, Environment, and climate change officers,

were considered for interviews of 8 people in two districts. In the same way, two officers, one dealing with agriculture and another dealing with livestock, were chosen at each sector, making 16 officers from six sectors. At the central level, 370 officers were identified in 7 institutions dealing with agriculture, livestock and environment or climate change sectors. Only 23 were qualified as they dealt with the subject of research. Further, among 267 researchers and experts identified in high learning and research institutions, only 19 were interviewed based on their involvement in agriculture, livestock, environment, or climate.

3.7 Sample Frame and Sample Size

Different sampling techniques were used at various levels and different targeted populations. To determine the sample size for all levels, the researcher relay on the Slovin formula of sample calculation taken from the study of Williams (2013) where: $n = \frac{N}{1 + (N * (e)^2)}$. Where "n" is the sample size, "N" is the total population, and "e" is the level of significance or margin error. The Slovin's sample calculation formula is flexible, so the researcher diversified the margin error from one given population category to another. This was made with a focus on the weight a certain population category has in the entire study. The main target population for the study is the agro-pastoral households in Gatsibo and Nyagatare Districts. Table 3.2 shows the sample calculated for households.

Table 3.2: Sample distribution and selection for sectors in Umutara Region

Sectors	Total targeted population	Sample Size	Sampling Method
Number of sectors (14 of Gatsibo and 14 of Nyagatare Districts)	28	$n=28/(1+(28*(0.3618730)^2))=6$	Systematic sampling method
Rwimiyaga	3,499	$n=3,499/(1+(3,499*(0.106499)^2))=86$	
Nyagatare	3,396	$n=3,396/(1+(3,396*(0.0109090)^2))=82$	
Karangazi	3,390	$n=3,390/(1+(3,390*(0.111917579)^2))=78$	
Kabarore	3,046	$n=3,046/(1+(3,046*(0.11047641323)^2))=80$	
Matimba	2,317	$n=2,317/(1+(2,317*(0.1182820840)^2))=70$	
Rwimbogo	2,247	$n=2,247/(1+(2,247*(0.10774874680)^2))=84$	
Total	17,895	480	

Source: NISR and researcher calculations, 2021

Reference made to Table 3.2, the sample calculation was made from 28 sectors of the former Umutara region (14 sectors from Gatsibo District and 14 sectors in Nyagatare District). Thus, the researcher got 6 sectors to be evaluated as a sample size from 28 sectors. Using systematic sampling, the sample was taken from total agro-pastoralists in selected sectors using data available at the sector level. To select sectors 6 sectors from 28 sectors in the two districts, systematic sampling was also used. Thus, six sectors were selected, including Rwimiyaga, Nyagatare, Karangazi, Kabarore, Matimba and Rwimbogo.

For each sampled sector, a sample size was calculated based on a total sample of 480 households for two districts. Thus, from Rwimbogo, only 86 households were

assessed, 82 from the Nyagatare sector, 78 from the Karangazi sector, 80 from Kabarore sector, 70 from Matimba sector and 84 from Rwimbogo sector.

3.8 Sources of Data

Data used in this thesis were drawn from both primary and secondary sources.

3.8.1 Primary sources

The researcher in the study area directly collected primary data. The researcher collected primary data from households in Nyagatare and Gatsibo districts. This data was collected using a questionnaire distributed to 480 heads of sampled agro-pastoralist households. Additional primary data were obtained from focus group discussions held with leaders of agro-pastoralist cooperatives and local leaders and interviews conducted with key informants selected in various ministries, agencies, and research institutions at the central government level.

3.8.2 Secondary sources

Secondary data refers to information gathered by parties other than the primary user (Schutt, 2006). Common sources of secondary data in the social sciences include censuses, government agency information, organizational records, and data initially acquired for other research reasons (McCaston and Katherine, 1998). In this thesis, secondary data were obtained from documents and reports held by various institutions such as the Rwanda Meteorological Agency, the National Institute of Statistics of Rwanda, the Ministry of Environment, the Rwanda Environment Management Authority, the Ministry of Agriculture, the National Agriculture and

Animal Resources Board as well as Ministry of Disaster and Risk Management and available data at district and sectors offices. Other secondary data were drawn from the thesis and other research books on climate change and agro-pastoralism.

3.9 Data Collection Methods

In this study, a questionnaire, interview, and focus group discussion were used to collect primary data, while a document review was used for secondary data collection.

3.9.1 Questionnaire surveys

Bernard (2006) states that a questionnaire technique tends to obtain information on opinions, attitudes and beliefs, behaviour, and other characteristics of a given population in questioning the concerned and targeted population. To collect accurate and reliable data, prepared a semi-structured question composed of two dimensions: closed-ended questions and open questions (Appendix 3). This kind of questionnaire facilitated respondents to offer suggestions and recommendations on what they hope would be improved to cope with the impacts of climate change and its impacts. The questionnaire was used to collect data from heads of households in selected villages.

3.9.2 Semi-structured interviews with key informants

A semi-structured interview is a face-to-face, interpersonal role situation in which an interviewer asks respondents questions tailored to elicit research-relevant responses (Glaser *et al.*, 2009). A semi-structured interview guide was utilized to collect data and opinions from experts and researchers at several central government offices and

Ministries. The researcher created a list of themes and topics to be covered with a combination of open-ended, closed-ended, and Likert scale questions.

Given that this research aimed to collect information related to climate change and agro-pastoralism, the researchers interviewed experts and officials dealing with environment and climate change, agriculture, natural resources and livestock from planning, research and technical selected. Thus, at the district level, officers dealing with the subject matter included an agronomist, a veterinary officer and District Environment Officer. In the same way, two officers one dealing with agriculture and another dealing with livestock, were selected for each sector.

At the central government level, 7 institutions dealing with agro-pastoralism, environment, and climate change were selected sectors. Institutions considered included the Rwanda Agriculture Board (RAB), Rwanda Environment Management Authority (REMA), Rwanda Green Fund (FONERWA), Ministry of Agriculture (MINAGRI), Ministry of Environment (MoE), Rwanda Water Board (RWB), and National Agriculture Export Board (NAEB). Further, researchers and experts in high learning and research institutions were interviewed based on their involvement in agro-pastoralism, environment, or climate research. These include University of Rwanda (UR) experts, the National Industrial Research Development Agency (NIRDA) and the College of Agriculture and Animal husbandry.

3.9.3 Focus Group Discussions

A Focus group is a form of qualitative research in which a group of people are asked about their perceptions, opinions, beliefs, and attitudes towards a subject of study (Andrews *et al.*, 2012). A focus group was conducted on the non-household's population or sampled elements. Eight focus group discussions were conducted by the researcher (2 focus groups at the district level and 6 focus groups at sector level for agro-pastoralist leaders). Each focus group was composed of an average of 10 elderly including women and men. Focus group discussion focused mainly on the potential role of indigenous knowledge and the challenges of its incorporation in the formal adaptation process.

3.9.4 Documentary literature review

Bailey (1978) defined a documentary literature review as the careful reading, understanding and analysis of written materials containing details on the study. A documentary study is the data collection process based on reading books and documents relevant to the study. Various reports, strategic plans and policy documents related to climate change, indigenous knowledge and agro-pastoralism were reviewed.

Under this research, documents were requested from different agencies. Data available in these documents were used as secondary data to complement primary data from the household survey, focus group and interviews and enrich the subject under study in response to research questions. Table 3-3 summarizes the data source and responses to research questions.

Table 3.3: Source of data and data collection methods by research questions

Research questions	Source of data	Data collection methods
How does the local community perceive continuing climate changes and associated effects?	Primary data	Questionnaire Interview with informants Document review Field observations
What is indigenous knowledge developed by agro-pastoralists to cope with changes in climate patterns?	Primary data Secondary data	Questionnaire Interview with key informants Document review
What is the contribution of indigenous knowledge on adaptation to climate change in agro-pastoralism in the study area?	Primary data	Focus group discussion Interview with key informants Document review

Source: Researcher methodology,2021

3.9.5 Observations

Field observation is a qualitative research technique that offers an intimate perspective of the community and its environment (Anne, 2003). Through observing and engaging with people on the topic of interest or the issue at hand, this approach yields a profound comprehension of the challenges within their local context. The research used this methodology to observe and understand some of reported indigenous knowledge but also some effects of climate change in the stud area. The researcher used some photos to illustrate some findings.

3.10 Data Analysis, Interpretation and Presentation

Analysis, interpretation, and presentation of data are crucial research tasks. The objective of data analysis is to obtain information that is usable and valuable.

Whether the data is qualitative or quantitative, the analysis describes and summarizes the data, identifies links between variables, compares variables, and distinguishes between variables and predicted outcomes (Bruscia, 2005). Qualitative and quantitative data were analyzed, interpreted, and presented in this thesis.

3.10.1 Qualitative data analysis

Typically, qualitative data consists of words, audio or visual recordings, and observations, rather than statistics (Fisher, 2010). Focus group discussions and interviews with key informants were utilized to collect qualitative data. All recorded interviews were transcribed, translated, and entered Microsoft Word documents. The responses were then separated into two groups: local government officials and farmers/livestock owners. Using a content analysis methodology, all categories and themes were evaluated and filtered based on their utility in answering the research objectives.

3.10.2 Quantitative data analysis

Systematic collection and evaluation of measurable and verifiable data is quantitative data analysis. It includes a statistical framework for evaluating and analyzing quantitative data (Creswell, 2007). In this study, questionnaire-derived quantitative data were analyzed using the Statistical Package for Social Science database (SPSS version 20.0). This software was useful for generating straightforward descriptive statistics, such as frequencies, percentages, and cross-tabulations. The results were then displayed using tables, bar charts, and pie charts, with interpretations based on frequencies and percentages.

3.11 Validity and Reliability of Research Instruments

3.11.1 Validity of the research instruments

The validity of a research instrument assesses the extent to which it measures what it is designed to measure (Mohajan and Haradhan, 2017). To check the validity of the research instrument, different methods were used. First, instruments prepared were compared to similar instruments used National Institute of Statistics of Rwanda (NISR). Further, the pre-test was conducted by randomly selecting 25 respondents from Nyagatare and Gatsibo districts in different villages. The Content Validity Index (CVI) was used to estimate the instrument's validity before conducting the survey.

Cronbach's Alpha coefficient demonstrates the dependability statistics at acceptable levels of alpha, ranging from 0.70 to 0.95, but a maximum alpha value of 0.90 has been proposed (Tavakol and Dennick, 2011). Last but not the list, these instruments were shared with NISR for verification and approval, and approval was issued (Appendix 1). This gave more confidence in the instruments' validity.

3.11.2 Reliability of research instruments

Reliability is the extent to which results are consistent over time and accurately represent the total population under study (Joppe, 2000). In this research, reliability was tested using a pre-test study and the level of consistency was calculated, and "r" was found to be greater than 70% of all items assessed. This gives a guarantee for

using the research instruments and ensuring their consistency and ability to provide accurate and reliable information responding to the study objectives.

3.12 Ethical Consideration

The collected information was treated confidentially, and participants were informed of the objective and confidentiality of the study. The participants were notified of their rights and access to the investigation's conclusions if a question requiring the use of names, letters and numbers were used instead.

The researcher ensured that the language used did not cause any harm to the participants in terms of psychological, social, economic, and physical aspects. In addition, the guideline established under COVID -19 was complied with to safeguard the safety of participants. This includes social distancing use of sanitizers, and facemasks. Furthermore, a research letter from the Open University of Tanzania authorizing him to collect data (Appendix 2), and the Visa delivered by the National Institute of statistics in Rwanda (Appendix 1) were presented to relevant institutions as requested. A consent statement was also signed by respondents and the researcher (Appendix 3). Last but not least, the researcher committed to avoiding plagiarism and where others' work was used, reference was provided.

CHAPTER FOUR

FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter presents the research results including data from questionnaires, interviews with key informants and secondary data obtained from various ministries and agencies. The first section of this chapter presents respondents' socio-demographic characteristics, including age, sex, marital status, and main source of income. The second section presents the perceived changes and effects of climate change on agro-pastoralism in the region, while the third section presents the vulnerability assessment results. The fourth section document the indigenous knowledge identified and the fifth section assess challenges, importance and approaches to integrate indigenous knowledge into formal adaptation strategies and actions.

4.2 Socio-Demographic Characteristics of the Respondents

4.2.1 Age of the respondents

Table 4.1 indicated that most respondents, 302 (62.9%), were between 36-65 years of age, followed by 65 years and above with 107 (22.3%). The 18-35 represent only 71(14.8%) of the respondents. Two factors can explain the presence of a small percentage of young people: one is that the selection criteria considered people above 18 years also, but also it was reported that most of the young people prefer to migrate to urban areas, especially in Kigali leaving agro-pastoralism managed by older adults.

Table 4 1: Age of respondents in the six sectors covered under this research

Age of respondent	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiyaga (n=86)		Grand Total (n=480)	
	f	%	f	%	F	%	f	%	f	%	f	%	f	%
18-35	12	15.0	13	16.7	11	15.7	15	18.3	6	7.1	14	16.3	71	14.8
36-65	51	63.8	40	51.3	48	68.6	55	67.1	59	70.2	49	57.0	302	62.9
65+	17	21.3	25	32.1	11	15.7	12	14.6	19	22.6	23	26.7	107	22.3
Grand Total	80	100	78	100	70	100	82	100	84	100	86	100	480	100

Source: Questionnaire results, 2021

4.2.2 Sex of respondents

As presented in Figure 4.1, males were the majority, 284 (59.2%) of all respondents, while women represented 196 (40.8%). This is opposite to the general distribution of the population in Rwanda where females slightly outnumber males, with 111 females per 100 males (NISR, 2012). This higher proportion of males can be justified by the survey methodology that targeted agro-pastoralism mainly done by Rwanda males.

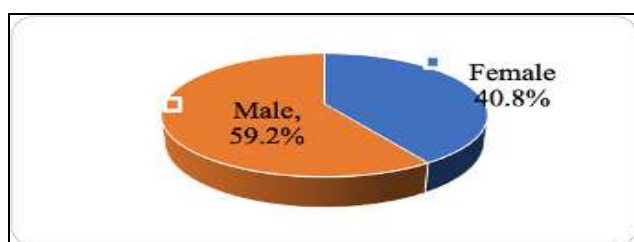


Figure 4.1: Distribution of respondents by sex

Source: Questionnaire results, 2021

4.2.3 The main source of income of respondents

As presented in Table 4.2, cattle rearing largely outnumbers other activities, with 285(59.4%) of all respondents. The situation is similar across all six sectors because of the location of the study area in the agro-pastoral region, where livestock is the

main activity. Growing crops and small businesses come second, with 71(14.8%) of the respondents.

Table 4.2: Main source of income among respondents per sector

Main Income Sources	Kabarore		Karangazi		Matimba		Nyagatare		Rwimbogo		Rwimiyaga		Total	
	n= 80	%	n= 78	%	n= 70	%	n= 82	%	n= 84	%	n= 86	%	n= 480	%
Full-time job	11	13.8	5	6.4	6	8.6	7	8.5	17	20.2	7	8.1	53	11.0
Growing Crops	11	13.8	17	21.8	10	14.3	11	13.4	8	9.5	14	16.3	71	14.8
Small Business	13	16.3	12	15.4	11	15.7	10	12.2	15	17.9	10	11.6	71	14.8
Sub-Total	35	43.8	34	43.6	27	38.6	28	34.1	40	47.6	31	36.0	195	40.6
Cattle keeping	45	56.3	44	56.4	43	61.4	54	65.9	44	52.4	55	64.0	285	59.4
Grand Total	80	100	78	100	70	100	82	100	84	100	86	100	480	100

Source: Questionnaire results, 2021

This was also observed earlier by Delgado (2005) that livestock rearing, or animal husbandry is one of the fastest-growing agricultural subsectors in Rwanda. Animal husbandry in Rwanda, the share of agricultural Gross Domestic Product (GDP), is about 33% and is rapidly increasing (Delgado, 2005). According to Rosegrant *et al.*, (2009), this growth of animal husbandry in Rwanda is driven by the rapidly demand for livestock products, which is driven by population growth, urbanization and rising incomes.

4.2.4 Highest level of education attainment

Survey results (Table 4.2) indicate that most respondents in the study area, 196 (40.8%) have completed only primary schools, followed by secondary school and vocational training schools with 53(11%) and 18(3.8%), respectively. Those with no formal education represent 89(18.5 %), while those who have completed university

represent 35(7.3%). This is partly due to the effective Rwanda's Education Sector Strategic Plan (ESSP), 2018/2019 – 2023/2024 (Karareba *et al.*, 2019), which recognizes pre-primary education as foundation for future learning. The Government of Rwanda commits to expanding access to three years of early learning for children aged 3 to 6, with the national goal to increase access to 45% of children by 2023/2024 (Paxton, 2012); hence more graduates in primary education compared to other levels.

At the sector level, the distribution of female and male respondents by the highest level of education does not differ much among the six sectors covered under this research. The proportion of women who attained primary school is slightly lower than that of men in the area, with 94(48%) and 102(52%), respectively. At the secondary education level, the percentages are 19(37%) for women and 34(63%).

Table 4 3: The highest level of education attained

Level of education	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (nN=84)		Rwimiyaga (n=86)		Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Complete University	7	8.8	6	7.7	4	5.7	1	1.2	13	15.5	4	4.7	35	7.3
Incomplete Primary	14	17.5	17	21.8	13	18.6	17	20.7	12	14.3	16	18.6	89	18.5
No formal school	14	17.5	14	17.9	13	18.6	17	20.7	14	16.7	17	19.8	89	18.5
Primary	31	38.8	36	46.2	26	37.1	34	41.5	29	34.5	40	46.5	196	40.8
Secondary	10	12.5	3	3.8	11	15.7	12	14.6	10	11.9	7	8.1	53	11.0
Vocational	4	5.0	2	2.6	3	4.3	1	1.2	6	7.1	2	2.3	18	3.8
Grand Total	80	100	78	100	70	100	82	100	84	100	86	100	480	100

Source: Questionnaire results, 2021

Contrary to earlier observations (Slegh & Kimonyo, 2010), Rwanda has achieved gender parity in access to primary school education since 2001 (in 2001, net enrolment for girls was 76.1% and for boys it was 74.4%). In 2013, females' net enrolment in primary school was 97.5% and boys was 95.7%. At the primary school level, female staff members outweigh male staff members by 52.8% to 47.2%. Girls proceed through first grades with fewer repetitions and dropouts than males and are more likely to finish primary education at the proper age (Ossom et al., 2012).

4.3 Perceived Climate Changes and Associated Effects in the Study Area

This section responds to the first specific objective of this research, which focused on how the local community in the study areas perceived climate changes over time. It also presents how climatic changes have affected their livelihoods, socio-economic activities, and local ecosystems.

4.3.1 Knowledge of local community about climate change and variability

Before understanding the perceived effects of climate change, it was important to understand the level of community knowledge on issues about climate change (Figure 4.2).

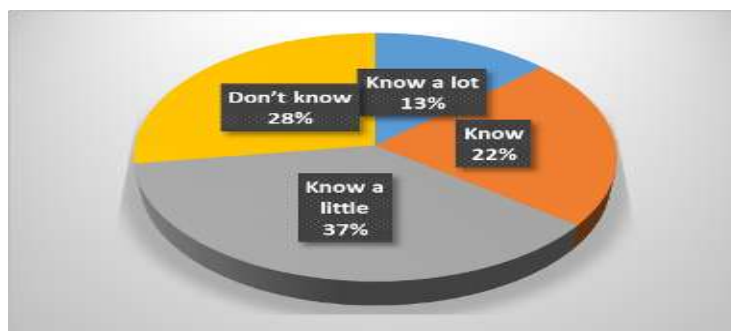


Figure 4.2: Knowledge of the local community about climate change and variability

Source: Questionnaire results, 2021

Figure 4.2 indicates that 178(37%) of all respondents have little knowledge about climate change. The fraction of people who reported having sufficient knowledge about climate change and climate variability is equal to 107(22%) while 63(13 %) reported having a lot of information about climate change. In an interview with an environmental specialist at Rwanda Management Authority, he indicated that

“There is ongoing training and awareness programme to educate people about climate change. However, due to lack of funds, these training are only provided to few people where climate change projects are being implemented”.

During Focus group discussion at the district and sector levels, it was reported that

“Most people are aware of climate change because they are experiencing its effects. They provided different examples, including the length of the dry season, changes in planting time, and the amount of rain received during rainy seasons”.

Further, the discussion revealed that most people know about climate change because they have been trained. It was worth noting that the study was conducted in a region which has benefited from different climate-related projects implemented. Hamilton and Keim (2009) indicated earlier that in Africa and many parts of the World, anthropologic climate science denial persists among the public because individuals lack sufficient information, have a poor understanding of the matter, or associate climate science with conspiracy theories and the like. A recent survey from Africa suggests that only 56% of the continent’s population has heard about climate change and about 20% believe that ordinary citizens can do nothing to stop climate change (Afro-barometer, 2019).

4.3.2 Perceived climate changes in the study area

To understand climate changes perceived by the local community, the researcher asked respondents to list any change observed over the last 30 years. Table 4.4 portrays findings from this research on climate changes reported by respondents.

Table 4.4: Local community's perception of climate change at the sector level

Local community's perception	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiyaga (n=86)		Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Decreased amount of rainfall during the rainy season	71	88.8	69	88.5	62	88.6	73	89.0	75	89.3	77	89.5	427	89.0
Increased length of the dry season	74	92.5	72	92.3	65	92.9	76	92.7	78	92.9	80	93.0	444	92.5
Decreased length of the rain season	57	71.3	55	70.5	49	70.0	58	70.7	59	70.2	61	70.9	339	70.6
Late onset of rain days	48	60.0	46	59.0	42	60.0	49	59.8	50	59.5	51	59.3	286	59.6
Increase of strong winds events	68	85.0	66	84.6	60	85.7	70	85.4	71	84.5	73	84.9	408	85.0
Increasing temperature of the area	51	63.8	49	62.8	44	62.9	52	63.4	53	63.1	54	62.8	304	63.3
The decreasing temperature of the area	56	70.2	55	70.1	49	70.9	57	70.3	58	70.6	60	70.8	337	70.2
Total	80	100	78	100	70	100	82	100	84	100	86	100	480	100

Source: Questionnaire results, 2021

From Table 4.4, most respondents in all 6 sectors 71(88.8%) for Kabarore, 73(89.0%) for Nyagatare, 69(88.5%) for Karangazi, 62(88.6%) for Matimba, 77(89.5%) for Rwimiyaga and 75(89.3%) for Rwimbogo that the rainfall amount was decreasing. At the same time, survey data indicates that more than 70% of agro-pastoralists from six sectors, including 57(71.3%) from Kabarore, 58(70.7) % from Nyagatare, 55(70.5%) from Karangazi, 49(70.0%), from Matima, 61(70.9% from Rwimiyaga and 59(70.2%) from Rwimbogo perceived that the rainy seasons are shorter compared to some years back.

In an interview with agro-meteorology specialists, he confirmed this tendency. He indicated that historical data available at Gabiro meteorological station show a decrease in rainfall in the Eastern province over the last 30 years. Furthermore, the agro-meteorologist indicated that the rainy season has decreased while the dry seasons are becoming longer. This was also observed earlier (Lyon and DeWitt, 2012), who indicated that the rains have declined since 1985 in the African continent, with major consequences for livelihoods.

In the boreal spring, a faster movement of the rain band over Eastern Africa is responsible for the shortened day. The decrease in precipitation, according to Wainwright *et al.*, 2019), was caused by a rise in sea surface temperature in the north during the boreal summer and in the south during the austral summer. This causes a higher-pressure gradient and, thus, a faster movement of the rain band during the entire January–August period (Hastenrath *et al.*, 1993).

4.3.3 Perceived causes of climate change in the study area

Most of the respondents seem to clearly understand the causes of climate change.

Some of the reported causes are also mentioned in scientific research (Figure 4.3).

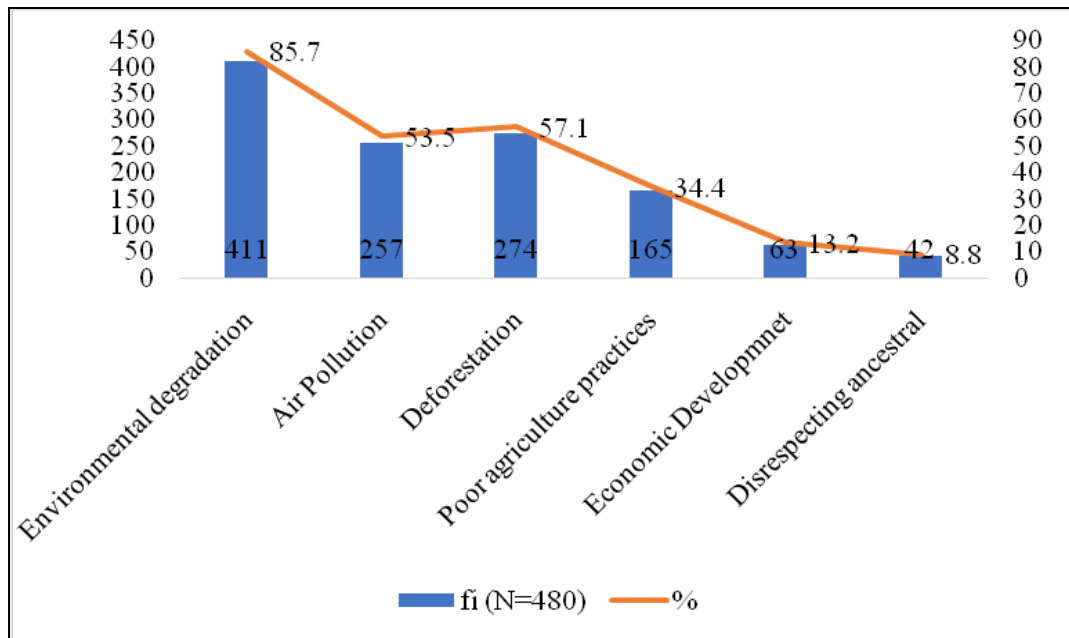


Figure 4.3: Perceived causes of climate change and variability in the study area

Source: Questionnaire results, 2021

At both district levels, a majority of respondents, 411(85.7%), reported environmental degradation as the main cause of climate change, followed by deforestation with 274(57.1%). Air pollution comes third with about 257(53.5%) respondents, while 165(34.4%) of the respondents in the area reported poor agricultural practices such as burning crop residues and rangelands. Further, a good number of respondents perceived economic development and supernatural forces as other factors causing climate change, with 63(13.2%) and 42(8.8%), respectively.

The same results were provided in all 6 sectors, as shown in Table 4.5.

Table 4.5: Reported causes of climate change and variability by sector

Perceived causes of climate change risks by Sector	Kabarore (n=80)		Karanga zi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiya ga (n=86)		Grand Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Environmental degradation	69	85.7	67	85.9	60	85.7	70	85.4	72	85.7	74	86.0	411	85.6
Air Pollution	43	53.75	42	53.8	37	52.9	44	53.7	45	53.6	46	53.5	257	53.5
Deforestation	46	57.5	48	61.5	41	58.6	47	57.3	48	57.1	49	57.0	274	57.1
Poor agriculture practices	28	35	27	34.6	24	34.3	28	34.1	29	34.5	30	34.9	165	34.4
Economic Development	11	13.75	10	12.8	9	12.9	11	13.4	11	13.1	11	12.8	63	13.1
Disrespecting ancestral	7	8.75	7	9.0	6	8.6	7	8.5	7	8.3	8	9.3	42	8.8
Total	80	100	78	100	70	100	82	100	84	100	86	100	480	100

Source: Questionnaire results, 2021

As presented in Table 4.5, 69(85.7%) of the respondents for Kabarore, 70(85.4%) for Nyagatare, 67(85.9%) for Karangazi, 60(85.7%) for Matimba, 74(86.0%) for Rwimiya ga and 72(85.4%) for Rwimbogo perceived that environmental degradation was causing climate change risks. Another factor reported by most of the respondents is deforestation, reported by 46(57.5%) for Kabarore, 48(61.5%) for Karangazi, 41(58.6%) for Matimba, 49(57.0%) for Rwimiya ga and 48(57.1%) for Rwimbogo.

An interview with the climate change specialist in the Ministry of Environment confirms some of the causes of climate change reported by local communities. According to specialist, climate changes is mainly due to man-made actions that contribute to the degradation of natural resources and air pollution. Those actions include deforestation, monoculture, chemical fertilizer application and improvement burning of bushes and crop residue, as well as pollution of water bodies through

mining activities. Some of the actions that contribute to environmental degradation were confirmed during site visits through direct observation, as presented in Plate 4.1. Plate 4.1 show mining and brick making along the Umuvumba River, which affects limited water resources and contributes to deforestation due to the firewood used in burning bricks.



Plate 4.1: Mining activities on Muvumba River

Source: Fieldwork, 2021

4.3.4 Perceived climate change effects on environmental and socio-economic systems

Figure 4.4 indicates changes have affected communities' livelihoods but also local ecosystems. The effects of climate change on community livelihoods are the decline in annual household income which was reported by 424(88.3%) of the respondents. Other socio-economic effects were increased incidences of pests and diseases in crops, as reported by 432(90.1%) of the respondents. The majority of respondents reported food insecurity (400(83.3%)) and rural urban migration (278(58%)) of the respondents. This was supported by a previous study by Hallegatte *et al.* (2007) that projected that Eastern and Western Africa are the most affected African continent. In

the low-warming scenario, the median loss in GDP per capita could be about 9.9 %, and in the high-warming scenario, 16.0 % by 2050.

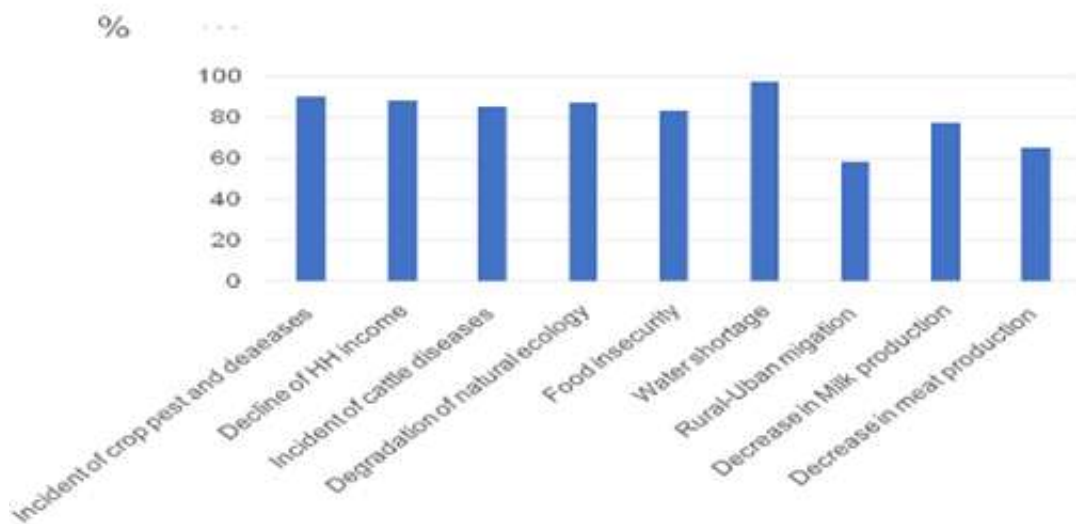


Figure 4.4: Socio-economic and environmental implications of climate change

Source: Questionnaire results, 2021

About 369(77%) and 264(55%) of the respondents reported decreases in milk and meat production. Regarding climate change effects on environmental and natural resources, respondents mentioned water shortages reported by 465(97%) and degradation of natural ecology 417(87.3%) of all respondents. Different studies, such as Kadzere *et al.* (2002), indicated high production of dairy cows is mainly affected by heat stresses, which lower the production of dairy cows. Berman (2005) indicated high producing dairy cows are more sensitive to heat stress. Consequently, milk production declines when metabolic heat production increases due to climate change as per heat stress (King *et al.*, 2006).

Discussions with agronomists at both Nyagatare and Gatsibo districts revealed that in recent years, new diseases and pests have been a problem for crops and livestock production. Reported diseases affected cassava and banana, such as severe cassava mosaic (Kirabiranya) and banana bacterial wilt (known as *Kabore* in the Local language). The most banana production losses were observed since the occurrence of banana bacteria wilt, which was first reported in 2005 and 2012 has spread to two third of Rwanda's territory.

The study on the negative effects of banana bacterial wilt on farmers' livelihoods assessed the banana output loss in Rwanda in 2007 to be 433 hectares, resulting in a loss of USD 638,675. (Niyonsaba, 2016). The World Bank report (2015) indicates that weather-related risks, such as drought, variable temperatures, floods, hailstorms, and landslides, have posed serious threats to agricultural production from 1995 to 2012. (Benjamin, 2016).

4.3.5 Impacts of climate change on agro-pastoralism

Results in Figure 4.5 present the perceived effects of climate change on the livestock systems in the community as reported by respondents.

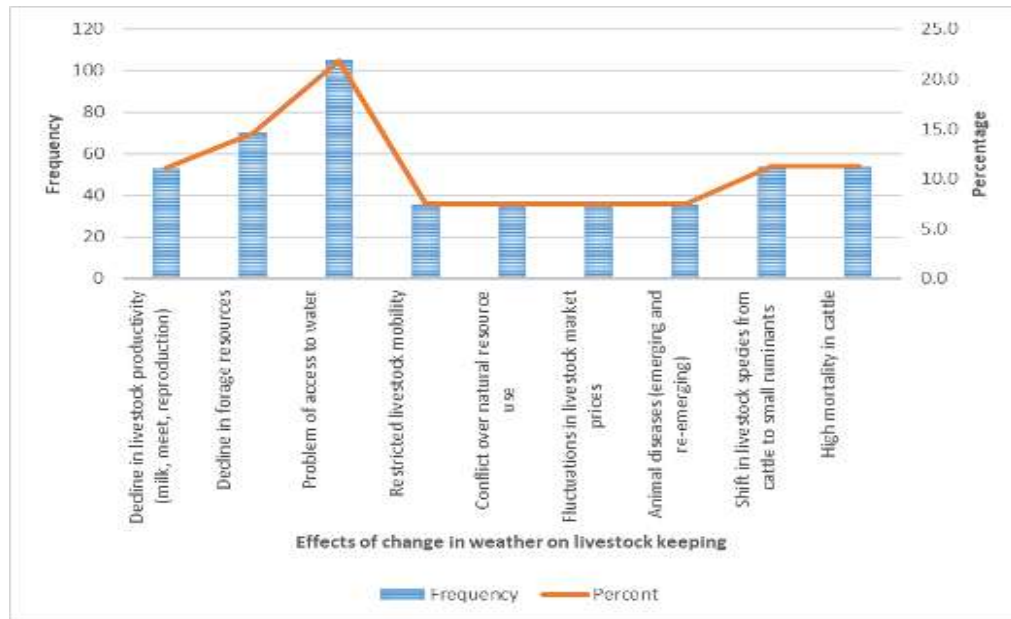


Figure 4.5: Perceived effects of climate change on livestock in study area

Source: Questionnaire results, 2021

As illustrated in Figure 4.5, water shortage comes first, with 480(100%) reported by respondents in terms of the effect of climate change on livestock systems. Other effects of climate change on livestock include a decline in forage resources which was reported by 348(72.5%) of the respondents, the decline in livestock productivity (milk, meat, reproduction), reported by 271(56.6%). High mortality rate of cattle was reported by 253(52.8%) and shifts in livestock species (from cattle to small Ruminants) by 247(51.6%) respondents. During visits to the area, it was observed that rangelands in the study area are severely affected by climate change-induced disasters, as presented in Plate 4.2.

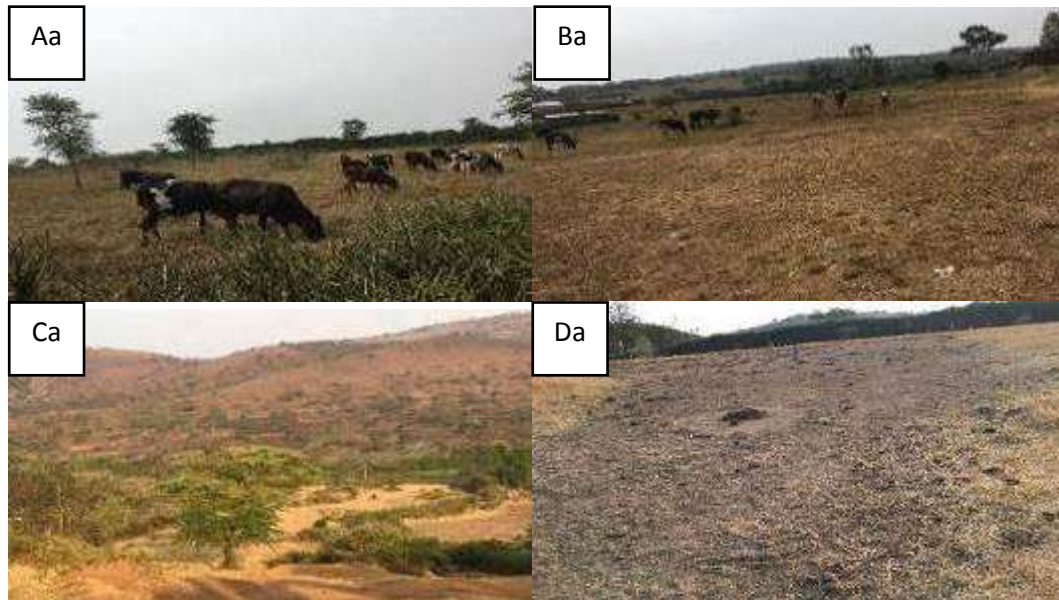


Plate 4.2: Status of rangelands during site visits

Source: Field observation, 2021

Plate A and B show cattle grazing on poor rangelands, which undermines their productivity in terms of milk and meat. Plates C and D show the general status of rangelands in the area, especially in prolonged droughts. The district veterinary officer in Nyagatare district reported that *“over the last 30 years, they have been observing a considerable decline in meat and milk production because cattle keepers are unable to find enough feeds due to poor conditions on rangelands. He reported that this situation is caused by overexploitation of rangelands but, more importantly, by reduced rainfall and prolonged dry seasons observed over the last few years”*.

4.4 Indigenous Knowledge Developed by Agro-Pastoralists to Cope with Effects of Climate Change

Indigenous knowledge and practices identified are grouped into four categories: knowledge used for weather forecasting, knowledge to address prolonged drought

and reduced rainfall, knowledge against pests and diseases and knowledge against strong wind events and water shortage. Were identified using the questionnaire administered to sampled households.

4.4.1 Indigenous weather forecasting practices in the study area

This research attempted to understand indigenous indicators used by the community to understand weather behaviour to plan their agriculture activities. Table 4.6 presents indigenous knowledge reported by local communities in terms of the weather forecast.

Table 4.6: Indigenous weather forecast practice in the study area

Indicators	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiyaga (n=86)		Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Observation of cloudy/sky colour and formation	66	82.5	59	75.6	58	82.9	66	80.5	69	82.1	69	80.2	387	80.6
Unexpected changes in temperature during the day	52	65.0	53	67.9	42	60.0	58	70.7	58	69.0	56	65.1	319	66.5
Direction and strength of winds,	47	58.8	42	53.8	44	62.9	49	59.8	51	60.7	49	57.0	282	58.8
Lightning and thunder,	35	43.8	38	48.7	33	47.1	37	45.1	37	44.0	42	48.8	222	46.3

Source: Questionnaire results, 2021

According to Table 4.6, the most predominant traditional knowledge in the study area is the observation of cloudy sky colour 387(80.6%), change of temperature during the day 319(66.5%) direction and strength of winds 282(58.8%), followed by

lightning and thunder with 222(46.3%). The results are in line with another study in an African country (Tume *et al.*, 2019) reported the indicators of indigenous knowledge of weather forecasting to include extreme temperatures (55.9%), star constellations (60%), as well as sequencing of yearly weather events (42.9%) to determine what the climate would be in a farming season. During an interview with community leaders, one respondent named Joseph Sebakire (65 yrs old) said:

”...unusual changes in temperature combined with heavy black clouds announces heavy rain while clear clouds there is good weather coming”.

The same person indicated that the presence of a rainbow suggests no rain. Though these indicators are not well documented and streamlined as scientific weather forecasting, they are almost the same as indicators used by meteorological services or scientists and weather forecasting. The key difference between indigenous and scientific knowledge is that indigenous knowledge uses only observation and feelings, while scientific weather forecasting uses sophisticated instruments to predict and interpret climate data. Weather observations can be taken manually by a weather observer by computer through an automated weather station (Iseh and Woma, 2013).

4.4.2 Practices to cope with prolonged drought and reduced rainfalls

The prolonged drought and low rainfall are the major concerns in the agro-pastoralism area of Gatsibo and Nyagatare Distracts. Over a decade, the local community has tried to overcome this challenging situation by developing different practices. Table 4.7 summarizes indigenous practices developed and used by agro-pastoralist.

Table 4.7: Indigenous practices against prolonged drought and reduced rainfall

Indigenous adaptation practices	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiya ga (n=86)		Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Farming and grazing along rivers and wetlands	42	52.5	48	61.5	45	64.3	48	58.5	52	61.9	59	68.6	294	61.3
Planting of drought-tolerant and early-maturing crops	34	42.5	34	43.6	38	54.3	47	57.3	51	60.7	45	52.3	249	51.9
Mulching of farmland	58	72.5	54	69.2	47	67.1	43	52.4	56	66.7	52	60.5	310	64.6
Food reserve in Granary (ibigega)	23	28.8	31	39.7	24	34.3	32	39.0	25	29.8	6	7.0	141	29.4
Reducing livestock herds	18	22.5	21	26.9	13	18.6	13	15.9	19	22.6	27	31.4	111	23.1
Indigenous prayers	5	6.3	7	9.0	5	7.1	4	4.9	3	3.6	3	3.5	27	5.6

Source: Questionnaire results, 2021

Indigenous knowledge identified by respondents are dominated by farming and grazing along rivers and wetlands with 294(61.3%) and planting drought tolerant and early maturing crops with 249(51.9%).

i. Farming and grazing along rivers and wetlands

During prolonged droughts or reduced rainfall, wetlands and riverbanks remain the only resources viable for agriculture and livestock production in the study area because the hillsides were dried up. Respondents reported that agriculture and cattle keeping are done only in wetlands and in river buffer zone during these challenging moments. Key water bodies mentioned by local people are Muvumba and Akagera rivers. The local community has practised this practice over decades. An interview

with the Nyagatare district livestock officer revealed that over time “cattle keepers have been moving along Akagera and Muvumba rivers in search for water and fodder during prolonged dry seasons”.

However, it was observed that this practice is disappearing with the introduction of the law on rivers and lakes protection. The head of Water pollution control officer in Rwanda Water Board said that “the law has established a buffer zone of 10 m from riverbanks and 50 m from lakes and in this buffer, zone were no agriculture or cattle keeping activities were allowed”. However, local communities reported that they are still using these areas though it is illegal, and there are risks of being fined if caught.

To help local communities, the government supported the construction of valley dams, but they did not last long and dried up only a few years after construction. The main reason for this failure, as reported by local communities, was the inadequate ecological studies that did not consider the local characteristics. The Eastern province is known to have a high level of evaporation. Those open valley dams are not a high level and unsuitable for the region. Though this practice has caused wetland degradation and conflicts between farmers and cattle keepers, it remains essential in arid and semi-arid regions, especially in climate change.

The practice is also undertaken by other communities in neighbouring countries and regions affected by prolonged drought. For instance, in Tanzania, agro-pastoralists depend on lowlands to undertake grazing during long drought seasons. In Addition,

varieties of crops including maize, rice, beans, sweet potatoes, cassava and cotton are grown in the lowland areas (Theodory, 2018).

ii. *Planting of drought-tolerant and early-maturing crops*

Local communities have adopted drought and early growing crops to prevent crop failure due to reduced rainfall or short rain season. Most of these crops were based on local seed varieties that do not provide high yields but are tolerant to reduced precipitation. Local communities reported that these crops are preferred to other crops introduced by government extension officers, mainly hybrids. According to them, hybrid seeds have high yields, but the probability of failure when the area experiences short spells of rain is very high.

Similar practices have been reported in other places in Rwanda, but with new farming practices introduced under land consolidation and crop intensification programs where farmers are encouraged to grow selected crops that are resistant to prolonged draught (Ngabitsinze *et al.*, 2011). Other authors have also confirmed the significance of this practice in climate change adaptation. Adoptions of climate-resilient crops was reported as one of the most important and practices combat food insecurity caused by unpredictable changes in weather patterns. Most importantly, this practice is essential for rural relying on domestic production for food security. Climate-resistant plant species and cultivars have enhanced tolerance to biotic and abiotic stresses (Dankher *et al.*, 2018). Such crops and crop varieties increase the climate change resilience of farmers. Nevertheless, despite their benefits, adoption

rates of certain cropping systems by small-scale farmers are lower than anticipated (Lin, 2011, Gollin, 2005).

iii. Mulching farmland

The practice of mulching is mainly known for horticulture, but local communities have adopted it for most crops, including a banana plantation. Long drought seasons contribute to moisture stress in the farmlands, and mulching practices reduce moisture stress. Furthermore, the mulching practice is known for its advantages in terms of water conservation and fighting the germination of weeds in farmlands. Currently, the government is doing a lot in terms of the provision of irrigation facilities to deal with climate change's effects. However, mulching practices remains popular among local communities, especially due to low investment.



Plate 4.3: Mulching practices in the study area

Source: Field observation, 2021

Plate A shows mulching practices in Banana Plantation, which aims to maintain moisture for long period to counter the effects of the prolonged dry season. On Plate B it's a mulching practice for vegetables (tomatoes) and is used for water conservation in small-scale irrigation schemes.

Mulching, which consists of coating the soil's surface with organic matter, is an ancient practice (Jacks et al., 1955) that was utilized to control soil moisture, temperature, nutrient loss, salinity, soil structure erosion, etc. Mulching has regained significance due to climate change, high temperatures, landslides, flash floods, etc. It has been established that various mulches minimize soil erosion by more than 90 percent compared to bare agricultural land (Mostaghini *et al.*,1994).

iv. Establishing food reserves in traditional Granary (ibigega)

Prolonged drought is often accompanied by food insecurity due to the failure of planted crops and the huge investment made by farmers during planting. To overcome these problems, agro-pastoralists took preventive measures to constitute food reserve just in case one or two seasons failed. One of these measures was to construct a traditional granary and put a portion of different products, especially when there was sufficient rains and high crop yields.

During such seasons, the households stored extra harvests that are not easily perishable such as maize, beans and cassava. The conserved products were then used during prolonged drought season. Interviewed member of local communities acknowledged that saving food for future use was helpful to most households in terms of food security. The challenging part of this practice was that only specific crops were stored, especially those not easily damaged, such as sorghum and maize.

Currently, the government is reintroducing this system in the form of post-post-harvest infrastructure. According to the chairman of the task force for post-harvest

and food storage in the Ministry of Agriculture. These infrastructures aim to improve food security. Unfortunately, this initiative was not built on a traditional granary system and communities were not involved in the design, which may justify the low rate of infrastructure use. Communities are concerned with the security of their crops in such shared facility and also the accessibility of this facility whenever they need to use their stored food.

The same indigenous knowledge has been documented by other authors, especially in Africa. For example, Djekore (2016) reported that in Mali, the community has endogenously developed a crop storage technique in the form of granaries as a response to climate change. This approach has allowed the Massa community to develop capacities and build governance and planning tools to master the technique of food conservation for food security.

The transmission of knowledge has been passed down through the generations. As safeguards are taken to protect production and combat food insecurity, the technology contributes to catastrophe risk reduction. It enables the selection of high-quality seeds in anticipation of the upcoming rainy season. Its execution requires the availability of biomass-powered eco-construction equipment. The granaries, which are constructed in banco-style structures with conical straw roofs, are simply modest storage buildings where harvest products are kept.

v. Undertaking non-farm activities

Diversification of income-generating activities is not new in the area. Repetitive long droughts and the decreased rainfall in the Eastern Province have reduced

agriculture and livestock production, pushing community members to get involved in non-farm activities. Those include fishing in Umuvumba and Akagera rivers and small trading. Others were involved in hunting practices, given that the area is closer to the Akagera National Park. However, this last practice is disappearing due to the protection of the park and other protected areas.

It has been established that non-agricultural activities would give an alternate source of income, especially considering climate change. The rural populace has diversified their means of subsistence and income-earning portfolio across agricultural, non-agricultural, and non-rural endeavours. Thus, non-agricultural income-generating activities have become a crucial element of rural households' efforts for sustaining their livelihoods (Agbarevo and Nmeragini, 2019). According to Ovwigho (2014), farmers, and rural farm families in particular, engage in a variety of non-farm income-generating activities to compensate for the income shortfall caused by the seasonality of primary agricultural production and to create a continuous income stream to meet the various household needs.

4.4.3 Indigenous practices against climate change-induced pests and diseases

Findings in table 4.8 summarize indigenous knowledge developed by agro-pastoralists to cope with an outbreak of climate-related pests and diseases.

Table 4.8: Indigenous knowledge to cope with climate-related diseases and pests

Indigenous knowledge	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiyaga (n=86)		Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Use of Locally made pesticides	23	28.8	31	39.7	28	40.0	53	64.6	34	40.5	37	43.0	206	42.9
Burning of pastures and farm residues	23	28.8	18	23.1	37	52.9	38	46.3	32	38.1	50	58.1	198	41.3
Early hand-weeding	47	58.8	47	60.3	46	65.7	53	64.6	42	50.0	52	60.5	287	59.8
Early planting	65	81.3	46	59.0	35	50.0	51	62.2	48	57.1	50	58.1	295	61.5
Use of indigenous medicines	13	16.3	22	28.2	33	47.1	28	34.1	35	41.7	29	33.7	160	33.3
Use of indigenous crops and livestock breeds	48	60.0	45	57.7	47	67.1	45	54.9	58	69.0	50	58.1	293	61.0

Source: Questionnaire results, 2021

The indigenous knowledge reported by respondents includes the use of locally made pesticides 206(42.9%), Burning of pastures and farm residues 198(41.3%), early hand-weeding 297(59.8%), early planting 295(61.5%), use of indigenous medicines 160(33.3%) and selection of indigenous crops and livestock breeds 293 (61.0%).

According to Kumar and Lassaad (2009), management of crops in general and pest management approaches vary among indigenous farmers practicing indigenous farming systems in different countries due to differences in indigenous knowledge accumulated over generations of close contact with nature for developing a sustainable and locally adapted agriculture system. As the land use system in this region is characterized by slash-and-burn agriculture in which crops and pests are managed by integrating indigenous knowledge and indigenous ecological knowledge of the communities, the indigenous farming system in northeast India is complicated

and distinctive. This dual knowledge has been acknowledged by the scientific communities of the world, and scientists are taking a keen interest in traditional agriculture since traditional farmers and their techniques may be of considerable assistance in addressing the weaknesses of modern pest management (Sofia *et al.*, 2006).

It was worth noting that in Rwanda, some reported practices such as burning pastures or crop residues are prohibited in regulations due to the reported effects on the environment. The district environment officer in Nyagatere informed that people still relying on these practices are doing it illegally and fined when caught. Others botanical-made pesticides are disappearing slowly due to the scarcity of tree species that were used. These pesticides were made from tree species harvested in Akagera National Park, such as *Aloe vera*, *Leonotis nepetifolia*, *Tetradenia riparia* and *Erythrina abyssinica*. District agronomist reported that local communities are currently relying on modern pesticides to control the spread of various crop pests to an extent.

Another traditional practice against pests and diseases is burning pastures and farm residues, limiting the spread of ticks and other crop pests. This practice is still applied and is seen as viable technology despite the environmental regulations prohibiting such practice. According to experts contacted, farmers who are caught burning the pastures or crop residue are charged with a fine that goes up to ten US dollars and other severe punishment that can include imprisonment when the burning

causes damages to third-party properties or protected areas. Agro-pastoralists are encouraged to use recommended pesticides which are mainly chemical pesticides.

4.4.4 Adaptation practices against strong wind events

The wind is another climate hazard that has hit the Eastern Province over decades especially due to its topographic conditions characterized by lowlands. In the face of these effects, agro-pastoralists have developed practices aiming to reduce effects of strong winds on crops and properties. Coping practices reported by respondents are presented in Table 4.9.

Table 4.9: Indigenous knowledge to cope with strong wind events

Indigenous Knowledge	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiyaga (n=86)		Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Sylivo-Pastoralism and Agro-forestry practices	58	72.5	53	67.9	44	62.9	55	67.1	57	67.9	53	61.6	320	66.7
The use of tree poles to support banana crops	40	50.0	39	50.0	32	45.7	45	54.9	44	52.4	40	46.5	240	50.0
Indigenous Vertical roof	14	22.5	17	21.7	12	17.1	9	10.9	11	13.1	19	22.1	82	17.1
The use of supernatural power	6	7.5	5	6.4	4	5.7	7	8.5	8	9.5	7	8.1	37	7.7

Source: Questionnaire results, 2021

Indigenous knowledge reported by respondents includes agroforestry with 320(66.7%) of respondents, the use of tree poles to support bananas with 240(50%), traditional construction techniques with 82(17.1%) and the use of supernatural power with 37(7.7%) of respondents. Similar practices have been reported in the region. According to Theodory (2016), the Haya community in Tanzania uses tree poles to support banana trees when carrying heavy fruit. The farmers have widely used this practice to adapt to strong wind events, which may fall into the banana plants. Further, Gyampoh *et al.* (2009) noted that the rural communities in Ghana recognised the relevance of having trees on their farm to shade their crops from high sunshine and protect them against strong wind.



Plate 4.4: Banana supported by Tree poles

Source: Field observation, 2021

Plate 4.4 presents the use of a pole to support the banana. Local communities reported that they have practised this for decades to reduce losses encountered during strong winds, which often accompany heavy rains. It was reported that the practice of using poles to support bananas had been challenged by the lack of poles because these poles were collected in natural forests and National Park, which are now protected. Local communities must rely on a few trees collected in their woodlots or modern poles made of steel, but the latter is very expensive.

Tree planting in rangelands or farmlands is another technique still used to encounter the effects of strong winds. These trees are mainly intercropped with other crops or planted in rangelands to increase land cover and provide shade for cattle during the hot season. Soil scientist also recommends such practice as it increases soil fertility. The District Environment Officer (DEO) reported that “they have received funds from Rwanda Environment Management Authority under National Adaptation Program (NAP) to implement Sylvo-Pastoralism in the district”. These funds will supplement local communities' efforts and contribute not only to controlling wind but also to improving pastures.

Construction of traditional houses with steep roof pitches is another indigenous knowledge to cope with strong wind events in agro-pastoralists. As seen in Plate 4.6, these houses with round forms have walls made of trees and mud and steep roof pitch made of grasses and bamboo. Local communities reported that such design was introduced to face strong winds that used to blow out the roof of their houses. Elsewhere, it has been proven that building geometry has a significant impact on

distribution of wind pressure on the surface of the roof and walls of the building. A pyramidal roof was found to have the lowest uplift compared to a gable roof and hip roof (Shreyas, 2015).



Plate 4.6: Indigenous steep roof pitch

Source: Field observation, 2021

It is difficult to find such structure in the area because they were removed in 2020 when the Government of Rwanda decided to eradicate all structures made of grasses in the "Turwanye Nyakansi" campaign. However, the same roofing techniques can be seen on modern housing but with tiles in the place of grasses and this design is now popular around Rwanda. This shows how indigenous knowledge can inspire modern design, as presented on Plate 4.7.



Plate 4.7: Modern steep roof pitch

Source: Field observation, 2021

4.4.5 Coping practices against water shortage

Water shortage is another effect of climate change in the study area. Table 4.10 summarizes indigenous technologies reported by respondents which are used during water shortage.

Table 4.10: Indigenous technology to deal with water shortage in the study area

Knowledge used by the local community	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiyaga (n=86)		Grand Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Rainwater harvesting	66	82.5	61	78.2	55	78.6	69	84.1	67	79.8	66	76.7	384	80.0
Planting of indigenous trees	29	36.3	34	43.6	23	32.9	36	43.9	34	40.5	38	44.2	194	40.4
The use of indigenous wells	38	47.5	37	47.4	31	44.3	49	59.8	55	65.5	52	60.5	262	54.6
Supernatural power	3	3.8	5	6.4	5	7.1	6	7.3	4	4.8	8	9.3	31	6.5

Source: Questionnaire results, 2021

As presented in Table 4.10, traditional knowledge against shortage of water includes rainwater harvesting reported by 384(80.0%) of respondents, planting of indigenous trees by 194(40.4%), the use of traditional wells by 262(54.6%) and traditional taboos 31(6.5%). These findings were in line with studies of Olatokun and Ayanbonde (2008) findings that 44% of respondents used indigenous knowledge in farming and drought risk reduction. Moreover, these findings corroborate those of the UNEP (2008), where indigenous knowledge is still an integral part of most African local communities and agriculture.

Rainwater is harvested either in mud-made calabashes or underground reservoirs constructed near houses or in artificial wells constructed in rangelands. On the other hand, tree planting is used as a catchment management approach aiming at controlling soil erosion and retaining water in the soil. Either radical or progressive terraces accompanying with this practice with ditches. This practise recommends indigenous trees, which do not consume a lot of water or do not affect crops and soil. Most the indigenous trees planted include species such as *Dracaena afromontana*, *Ficus thoningii*, *Erythrina abyssinica*, *Euphorbia tirucalli* and *Verminia amygdalena*. Some of these are presented on Plate 4.8.



Plate 4.8: Indigenous trees identified in study area

Source: Field observation, 2021

Using trees and agroforestry in climate change adaptation is not unique among agro-pastoralists in Rwanda. Scientific research has documented that forest and tree products, including timber and non-timber products, are essential in income diversification among many communities affected by climate variability and climate hazard risks. Rural communities use forest products as part of their coping strategies (i.e., in reaction to stresses) when crops fail due to drought. For example, McSweeney K. (2005) reported that during and after the dry spells of 2005–2006 in the semi-arid areas of Tanzania, households consumed forest products directly as part of their food intake and earned 42% of their total income from selling wild fruits, firewood, timber, and charcoal. In rural areas of Peru, gathering forest fruits, palm hearts, and other products is an important strategy for coping with floods (Gordon *et al.*, 2008). Forest products also play a part in post-disaster strategies in Honduras: rural households sold timber and other products to recover from land losses during Hurricane Mitch (Takasaki *et al.*, 2005).

4.5 Potential role of Indigenous Knowledge in Formal Adaptation to Climate Change

The last objective of this research was to establish the place of indigenous knowledge in adaptation to climate change. Investigating the role of indigenous knowledge involves understanding of challenges associated with the application of indigenous knowledge, the relevance of indigenous knowledge and opportunities offered by indigenous knowledge. This methodological approach helped to understand the potential contribution of indigenous knowledge and to provide guidance on how both indigenous and scientific knowledge can complement to address the effects of changing climate.

4.5.1 Relevance of indigenous knowledge on climate change adaptation systems

To understand the importance of indigenous knowledge, the researcher interviewed local community members, researchers and decision-makers on the importance and relevance of indigenous knowledge. In the process, the research attempted to understand how respondents rate the use of indigenous knowledge. At the community level, the questionnaire results, as presented in Figure 4.6, indicates that 255(53%) still agree that indigenous knowledge has a role to play in adaptation to climate change. Further, 40(7%) strongly agree that indigenous knowledge is useful in adaptation to climate change. On the other hand, 97(22%) disagree with the use of indigenous knowledge in dealing with current climate change effects.

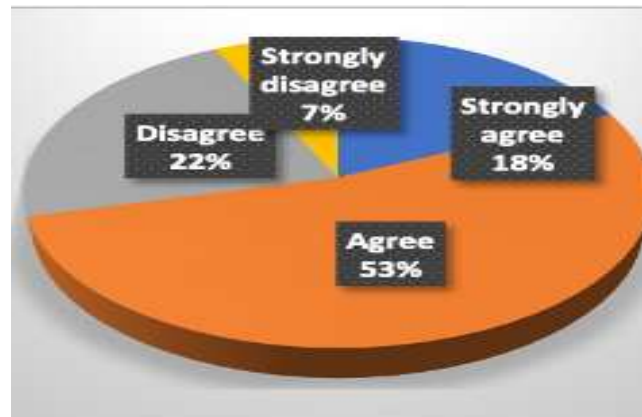


Figure 4.6: Pertinence of indigenous knowledge in climate change adaptation

Source: Focus Group Discussion, 2021

An obstacle to incorporating indigenous knowledge into collaborative management and mitigation plans is the perceived incompatibility between indigenous knowledge and Western science (Gamborg *et al.*, 2012). Recent studies and collaborations have contested this notion and have shown that the two ways of knowledge can be used together, partly because of their inherent differences (Kirsten and Kathy, 2013).

An interview with the head of research development in Rwanda Agriculture Board revealed that even scientists believe that indigenous knowledge, such as indigenous pesticides, mulching practices, and water conservation practices, can be used to adapt to climate change. As described in the previous section, some of the reported indigenous practices are still in use, and local communities rely on them to adapt to climate change-induced hazards. Other indigenous knowledge has been modernized and is being promoted by governmental agencies.

For instance, it was revealed that the government is implementing different projects aiming at addressing climate change effects, increasing livestock production and agricultural projects, including Muvumba multipurpose dam construction, Rwanda Dairy Development Project, building the capacity of a national institution for adaptation to climate change projects and Gabiro Agribusiness Hub Project (GAHP).

Though these projects mainly use western knowledge such as genetically modified seeds and chemical fertilizers, they have some practices that were traditionally used by local communities, such as silvo- pastoralism agroforestry and rainwater harvesting. This is an example of the synergy that can be introduced between indigenous knowledge and western knowledge. It was observed that local communities are not up taking some of the modern technologies, and recommendations are given by extension staff. For instance, 132(27.6%) of respondents said they prefer using their indigenous knowledge to control invasive weeds. In comparison, 207(43.3%) farmers are not enthusiastic about using chemical fertilizers and herbicides or improved seeds due not only to the high cost but also their potential impacts on the environment. This reluctance indicates some shortcomings of modern knowledge, which calls for identifying a new approach to enhance community ownership.

Some authors (Freeman, 1992; Iaccarino, 2003) have claimed, for instance, that indigenous knowledge systems can aid in the management of complex systems. Modern, or Western, science may not be best equipped for this purpose, as its vision

of the world is too confined by its specific empirical and analytical methodology, which in the past led to its success. Therefore, we should recall the contributions of past civilizations to our understanding of nature. Increasingly, such indigenous or indigenous knowledge is being used not only to discover novel medications, but also to derive new notions that may help us reconcile empiricism and science (Iaccarino, 2003).

During Focus Group Discussion, participants were asked to list the advantages of using indigenous knowledge in agro-pastoralism. The reduced cost adaptation technologies were ranked first in all 8-focus group discussions. For instance, it was reported that farmers who are using indigenous practices such as compost are saving a lot of money and the crop yield obtained is not different to the one of those using improved seeds and chemical fertilizers. Yet, the cost of locally made fertilizers is less expensive than chemical fertilizers. On the other hand, the high cost of western agriculture inputs pushes local communities to apply rates below the recommended rate, which also affects the expected yield.

During an interview with experts from the Ministry of agriculture, it was reported that even the Ministry is considering combining both knowledge will promote the use of indigenous compost and inorganic fertilizers. These experts confirmed that this practice had been tested under ongoing projects such as Sustainable Agriculture Intensification Project (SAIP), Land husbandry Water harvesting, and Hillside irrigation projects funded by World Bank and Kayonza Irrigation and Integrated Watershed Management Project (KIIWP) supported by International Fund for

Agriculture (IFAD). This approach will not help reduce the cost involved but also will be used to increase awareness among the local community.

Furthermore, an interview with Experts at the district level indicated that the government tends to reintroduce sylvo-pastoralism practices in the eastern savannah under the National Adaptation Program. According to the district Vice Mayor in charge of Economic Affairs in Nyagatare district, the proposed project intends to promote silvopastoral to strengthen livestock production (meat and milk) and increase forest cover in the Eastern Savanna.

The project documents found on the project website indicate that proposed activities include:(i) fencing off paddocks with drought-tolerant trees (such as *Grevillea*, *Acacia* or *Eucalyptus* sp.) to protect exposed soils from wind erosion and prevent livestock from grazing during pasture regeneration periods thereby promoting sustainable grazing practices, (i) planting drought-resistant trees (such as certain *Acacia* spp.) in rangelands to provide additional fodder and shade for livestock, wood for communities, protect soils against the effects of erosion (wind and water) and promote water infiltration; and (iii) planting fodder and medicinal plants for use by livestock and humans, respectively. This is a good indication that indigenous knowledge and disappearing practices are being brought back (REMA, 2020).

Another area highlighted by respondents which may show the importance of indigenous knowledge is community-based planning and participation. As documented by Chifamba (2013), different projects fail because beneficiaries were

not involved in the design, which ultimately affected their ownership level. Agro-pastoralists in the study area indicated that different environmental and resource management projects are designed in Kigali and brought to the field without proper consultation and participation of beneficiaries. The case reported by people interviewed in the study area was the construction of valley dams to respond to prolonged droughts and water shortage in the area. Initially, the initiative was helpful for the local community, especially during rainy seasons, but the project failed a few years later, and almost all valley dams are dried up.

Respondents attributed the reason for this failure to the government, which did not consider the local characteristic. Local communities and scientists interviewed believe this would have been avoided if planners had considered what the local community is already doing and provided support rather than bringing new technologies. Participants in group focus group discussion at sector level indicate that:

The government people came here and started digging these dams in different areas; there was not any research done before that. Then all water was channeled to these dams, and local communities were happy with the water. Unfortunately, a few months later, there was no more water, and all valley dams were empty because the area has water only in the rainy seasons and these open valley dams favor evaporation. Before, we had our small traditional dams, we used to cover them with grass and the water conserved was used during dry seasons.

4.5.2 Challenges of sustaining and promoting the use of indigenous knowledge

It would be fallacious to believe that indigenous knowledge is always the best solution or sustainability in climate change adaptation. The present research has identified significant challenges that need to be urgently addressed to enhance the benefits offered by indigenous knowledge in climate change assessment and adaptation process. Different challenges were identified during an interview with experts and during focus group discussions (Table 4.11).

Table 4.11: Causes of the disappearance of indigenous knowledge

Challenges	Ranks
Socio-economic transformation	1st
Poor reputation	2th
Decrease of the custodians	3nd
Exclusion in the formal adaptation	4rd
Absence of knowledge-sharing culture	5th
Vanishing of indigenous seeds, plant species	6th

Source: Results of Focus Group Discussion, 2021

As portrayed in Table 4.11, socioeconomic transformation and poor reputations were ranked 1st and 2nd-second major reasons for the disappearance of indigenous knowledge, respectively. This is in line with other research findings; for instance, Theodory (2013) reported that in the Ngoni River Basin, Tanzania, one of the main indigenous knowledge challenges is poor reputation within the community. Most the elders who perform those practices are considered by the community to be wizards, which carries a negative connotation. For instance, during discussions, some

participants associated indigenous knowledge with sorcery or considered their outdated practices. Some custodians of this knowledge are considered by some wizards (*abapfumu*). This perception discourages those who want to learn more about this knowledge, especially the young generations. In addition, the government institutions have failed to recognize and support indigenous knowledge and there is no mechanism to document and disseminate them.

Other challenges of traditional knowledge identified during Focus group discussions include the absence of knowledge-sharing culture or the disappearance of indigenous culture and practices easily addressed. Participants indicated that addressing this challenge requires awareness and adequate documentation of indigenous knowledge and importance. The attention should focus not only on local communities but also on scientists and experts who have a biased understanding of the role of indigenous knowledge.

On the other hand, there are challenges such as socio-economic development or exclusion of indigenous knowledge in the formal adaptation processes that require changes in policy formulation and investments. The socio-economic development brings new practices, beliefs and cultures, ultimately altering indigenous knowledge. For instance, the savannah region of the eastern province was primarily dedicated to cattle keepers, but now they are mixed with other communities. This has disturbed social structures used to generate indigenous knowledge among agro-pastoralists. Further, urbanization, market development introduction of a new education forms and religion have exposed indigenous knowledge.

Other areas that need more thought are the disappearance of indigenous seeds and medicinal plants. Over the last few years, research and outreach have focused on scientific discovery and put behind indigenous knowledge. For instance, agriculture agencies are putting their efforts into developing hybrid seeds not adapted to a prolonged drought season. In the same time context, respondents indicated that traditional medicinal plants had disappeared due to the lack of proper support for their conservation and multiplication. This has also been exacerbated by population pressure on forest resources.

Review of approved policies and strategic plans indicates that indigenous knowledge has been excluded in climate change assessment and adaptation. As highlighted earlier, national adaptation and mitigation plans are developed based on western knowledge, excluding local knowledge. As a result, the important role of indigenous knowledge in climate change adaptation and local characteristics is not captured in these documents.

Another challenge reported during the focus group discussion, as reported in table 4.11, is the exclusion in the formal adaptation. Participants indicated that much attention and investment focus technologies imported from western countries. According to most participants, traditional knowledge should be given the same attention, researched, documented, and validated, which can help in climate change adaptation.

Importantly, the omission of Indigenous knowledge is not accidental but rather

systematic. According to Berenstain *et al.*(2021), Cooke (2004), and Lloyd and Wolfe (2016), the suppression of Indigenous knowledge has been and remains a characteristic of settler colonialism and the oppression of Indigenous peoples in general.

On the other hand, interviews with key informants confirmed that the current adaptation practices focus on scientific knowledge, which has shown their challenges. For instance, during an interview with experts in Rwanda Environment Management Authority (REMA), it was revealed that even these introduced technologies are harmful to human beings and the general environment. It was reported, in the recent study conducted by REMA in 2018, that farmers are moving away from conventional and organic farming practices to increasing use of agrochemicals due to the introduction of inputs subsidy policy. Key identified impacts on the ecosystem include but are not limited to soil degradation and pollution, water pollution and disturbance of water table, new crop diseases, loss of micro-organisms, an increase of invasive species and low quality of products where pesticides and inorganic fertilizers are applied (REMA, 2018).

4.5.3 Opportunities offered by indigenous knowledge into formal adaptation strategies

The overall objective of this research was to assess indigenous knowledge's contribution to climate change adaptation. Findings presented in the previous sections indicated that agro-pastoralists are still relying on traditional practices to deal with the effects of climate change. At the same time, findings identified several challenges encountered in sustaining and applying indigenous knowledge. Further, in recent years, frequent and aggressive climate hazards have revealed challenges and limitations of this indigenous knowledge (Karki *et al.*, 2013).

According to the research findings, indigenous knowledge still plays a role in climate change adaptation. Indigenous knowledge can play a role at different levels of the adaptation process. This includes the data required for climate change assessment and predictions and can constitute a basis for designing adaptation strategies, especially at the household and community level. Further, indigenous knowledge can provide a platform for community engagement and consultation, enhancing participation and ownership. Finally, yet importantly, indigenous knowledge can provide information in formulating policies and procedures that address the real climate change issues affecting communities.

4.5.4 The implication of indigenous knowledge on policy formulation

Adaptation is fundamentally a local activity, and local knowledge should play a critical role in all adaptation-related decision-making processes (Karki *et al.*, 2013). Therefore, there is an urgent need to consider traditional knowledge and build an

adaptation plan based on local understanding and characteristics. Without such an approach, the proposed actions and strategies in the National Adaptation Plan will not address the real community challenges. To succeed, these actions and strategies need to be contextualized to a specific culture, location, and society (Karki *et al.*, 2013). Thus, adaptation plans should therefore, be customized to local socio-ecological systems and institutional frameworks.

Around the World, government and donor agencies have started using both traditional knowledge and scientific knowledge systems to deal with threats, hazards and vulnerability related to climate change. This approach is recognized with a good number of organisations (IPCC, 2007; UNFCCC, 2013). Acknowledging the role of traditional and local knowledge systems in climate-change adaptation would pass through the integration of these two knowledge systems. At this same time, both knowledge should be mainstreamed in all national policies and plans, especially those related to climate risk management.

It has been documented that both traditional and scientific knowledge systems have limitations in responding adequately to climate change challenges. These limitations are mainly due to the fact future climate is uncertain. Further, conditions and specific location of traditional and local knowledge have shortcomings when dealing with the high-exposure nature of climatic shocks (Karki *et al.*, 2013). Additionally, in many local communities, it is difficult to access western knowledge; hence, traditional knowledge remains the only resource at their disposal to cope with climatic and

natural disasters at the local level. This is mainly due to the cost involved with scientific knowledge, since most of them are developed in western countries.

Different research has demonstrated that the cost of adaptation technology can be a challenge in communities, especially when the specific characteristics of that community are not considered. For example, in introducing hybrid seeds as a response to seed and food insecurity in Zimbabwe, it was found that hybrid seeds' high cost, unavailability and unsustainability hindered their adoption (Progressio, 2009). Further, an interview with Experts in the Ministry of Agriculture indicated that the high cost of irrigation technologies introduced under different irrigation projects, such as Land husbandry water harvesting and hillside irrigation project, has hindered the implementation of projects. It was indicated that operational and maintenance costs remain high for small farmers.

Consequently, this research recommends changing the current approach used in policy formulation and implementation by combining indigenous and western knowledge as a way of designing appropriate adaptation strategies. This approach will allow policymakers to develop multi-level, multi-hazard and multi-disciplinary adaptation plans and create policies, strategies and programmes that build the resilience of communities. Some governments and donor agencies worldwide are already using indigenous and scientific knowledge systems to deal with risks, hazards and vulnerability induced by climate change (Karki *et al.*, 2012). This approach is also advocated by several national and international organizations (IPCC, 2007; UNFCCC, 2013).

4.6.5 Role of traditional knowledge in climate change risk assessment and predictions

Different authors have documented the role of traditional systems in climate change risk assessment and prediction, especially in weather observation, climate variability and hazards management (Ainka, 2016, Green *et al.*, 2010; Lefale, 2010). For instance, local knowledge in terms of agriculture seasons, behaviours of water bodies, and past disasters may constitute the baseline for assessing climatic changes and weather variability. Furthermore, traditional weather forecast indicators used by local communities can be used in monitoring the local climate or integrated into early warning systems for climate hazards. They can also be used in simplifying weather forecasting for use by ordinary farmers.

Further, it is believed that knowledge and practices used by local communities to cope with climate hazards are often rooted in social or livelihood practices that incidentally address hazards (Ainka, 2016). Building on these social practices and the wider sociocultural and political set-up would provide added value in developing adaptation strategies and actions for managing climate variability and change.

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4.5.6 Indigenous knowledge and community engagement and consultation

During interviews, respondents at the community level complained that policies and programs are designed at the central and district level and brought to the community level when they are ready for implementation. This approach has affected the successful implementation of these programs and policies due to the lack of ownership and the fact that these programs sometimes do not respond to the specific need of the local community. It has been documented that public agencies have not met the minimum requirements for consulting with the local community and have missed opportunities for meaningful communication and collaboration with custodians of indigenous knowledge and knowledge of local characteristics (Kirsten, 2012).

It is essential that state agencies and other stakeholders change that approach and establish clear, meaningful partnerships with local communities. This will help identify and address community needs and build on what is already being undertaken by local communities. The local community stressed that consultation should be two ways of communication where their views are heard and considered rather than receiving instructions from authorities (Hyland-Wood, 2021).

Community engagement and consultation will lead to successful integration processes and could create an equitable, participatory approach, knowledge exchanges, and collaborative processes. It would also enhance the capacity building of all stakeholders, public awareness, and a culture of continuity and sustainability. Further, this process should involve a periodic participatory assessment of targets and how well they have been achieved and outreach strategies, knowledge exchanges and adaptation of technologies. As result, the process will generate mutual learning experiences, problem-focused, demand-driven and project- or pilot-based approaches (Karki *et al.*, 2013).

Recent studies and research on building community resilience, especially in rural sets up, highlighted the importance of transferring and integrating a range of information using a shared learning dialogue and including indigenous and modern scientific techniques into the local social, political, and cultural context (Dixit and Khadka, 2013; Dixit *et al.*, 2014).

This learning brings together actors with different views, information, knowledge, and experience on the same ground for conversation using a participatory and problem-solving approach. Such an approach can reinforce reciprocal learning between local communities and scientists. Furthermore, using different channels and platforms can simulate continual reflection that enhances the culture of exchanging specific knowledge and perspectives between custodians of indigenous knowledge and external experts. A such approach may improve effectiveness in terms of decision-making in adaptation to climate and climate risk assessment.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the Findings

The main objective of this research was to assess the contribution of indigenous knowledge held by agro-pastoralists in eastern provinces in climate change adaptation. The study responded to three research questions to achieve this objective, which responded to four specific objectives.

The first objective was to assess the effects of ongoing climate change and non-climate changes on agro-pastoral systems. Key changes reported include changes in rainfall distribution, decreased amount of rainfall during the rainy season, decreased length of the rain season, late onset of rain days, an increase of strong winds events and increasing temperature of the area. Further, findings tend to agree that climate change is affected the region and, together with other changes in the socio-economic set-up, has affected the livelihoods of local communities. These changes have resulted in different effects on agro-pastoralism, including increased incidences of pests and diseases, increased diseases in human beings, a decline of annual average income, degradation of natural resources, food insecurity, increased water scarcity, and decrease in production and productivity.

The second objective was to document indigenous knowledge developed by local communities to deal with climate change effects. Identified indigenous practices

include adaptation practices against which are grouped under key effects. Adaptation practices against drought and reduced precipitations, pests and diseases, strong wind events and adaptation practices in facing water stress. However, these practices are despairing in the area and the country in general, the local community still believe in their importance.

The last objective of the research was to examine the role of indigenous knowledge in the formal adaptation process. This focused on identifying challenges, importance and opportunities offered by indigenous knowledge in designing adaptation knowledge. Challenges reported include those associated with community and public perceptions, such as poor reputation of indigenous knowledge and additional related socio-economic development and policy formulation processes. In terms of contributions of indigenous knowledge to climate change assessment and adaptation, findings revealed that indigenous knowledge could contribute in terms of policies and strategy formulations, in providing data in climate change assessment and design of adaptation actions at the community level and engagement and consultation.

5.2 Conclusions

This research assessed the contribution of indigenous knowledge held by agro-pastoralists in eastern provinces in climate change adaptation. Based on key findings, it can be concluded that climate change is a reality in the agro-pastoral region of Gatsibo and Nyagatare districts. Effects of climate change observed through prolonged drought and reduced rainfall, shortage of water resources, an outbreak of

climate-related pests and diseases, and strong winds events. These effects are felt by local communities, have affected their livelihoods, and reduced their annual income as livestock productivity.

However, over time, agro-pastoralists have developed indigenous practices to cope with ongoing climate and non-climate changes. Some of this knowledge is still applied by local communities, while others are disappearing. This research concludes that indigenous knowledge should be considered as the basis for the adaptation process, especially when designing community-based adaptation initiatives. Therefore, it is critical to assess the potential of indigenous knowledge in adaptation to climate change. The same approach should also be applied to modern or western adaptation practices, which at some points have failed to live up to expectations, especially when addressing local community challenges.

The existing conflict of hegemony between indigenous and scientific knowledge can be ignored to advance climate change assessment and adaptation processes that resolve community and global challenges. The focus should be on how the local community can be involved in the adaptation process and how existing local knowledge and context can be incorporated into modern knowledge to design programs and actions to reduce community vulnerability and enhance adaptive capacity and community resilience. Successfully adapting to climate change will depend on a close relationship between scientific knowledge and indigenous knowledge. This should be emphasized, especially in developing local action plans where the level of education and technical knowledge remain low.

5.3. Recommendations

- (a) Agro-pastoralists and local communities should be empowered and trained to facilitate the adoption and integration of indigenous knowledge into adaptation practices through simplified training and awareness, such as the Farmers Field School approach and formal training.
- (b) All indigenous knowledge that addresses climate change adaptation and assessment across the country and sectors should be identified and documented. This would include an evaluation of their efficacy, applicability and acceptability.
- (c) The consideration of indigenous knowledge should be on how the local community can be involved in the adaptation process and how existing local knowledge and context can be incorporated into modern knowledge to design programs and actions to reduce community vulnerability, enhance adaptive capacity and community resilience.
- (d) Indigenous knowledge found to be effective and acceptable within the community should be effectively incorporated into the design of adaptation actions especially community-based adaptation.
- (e) Formal recognition of indigenous knowledge with its values should be established and incorporated into National Climate Assessment and adaptation framework.
- (f) Awareness-raising program on the importance and role of indigenous knowledge should be undertaken for all stakeholders in climate adaptation. Awareness can

be raised through conferences, seminars, at national and district levels, or through community radios.

- (g) Research and initiative aiming at documenting, protecting, or implementing indigenous knowledge at national and community levels should be supported. This would help investigate the applicability of indigenous knowledge in specific areas such as catchment-based water management, climate change monitoring and knowledge management and transfer.
- (h) Additional research should be conducted to investigate the applicability of traditional knowledge in specific areas such as catchment-based water management, climate change monitoring and knowledge management and transfer.

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APPENDICES

Appendix 1: Questionnaire for Households in Nyagatare and Gatsibo Districts

Section 1: Background of Respondents

Questions	Explanation of codes	
1.1. Code and date of the questionnaire	1) Code: (egg: Gt001 or Nyg001) 2) Date: dd/mm/yyyy: .../...../.....	
1.2. Location	1) District, 2) Sector, 3) Cell, 4) Village,	
1.3. Civil status	01: Single 02: Married 03: Divorce 04: Widow or widower	
1.4. Age of respondent	01: (18-35) 02: (36-65) 03: (65+)	
1.6. Level of education	01: No formal school, 02: Incomplete Primary, 03: Primary, 04: Incomplete secondary, 05: Secondary, 06: Vocational, 07: Incomplete university 08: Complete University 09: Other (specify).....	
1.5. Profession	01: Farmer or/and livestock keeper, 02: Public servant, 03: Trader,	

	04: Student, 05: Unemployed, 06: Private servant, 07: Others (specify.....)	
1.6. Household size	01: Between 1-3, 02: Between 4-6, 03: Seven (7) and plus	
1.7.		
1.8. Number of educated persons in Household (formal education with certificate)	01: None, 02: Between 1-3, 03: Between 4-6, 04: More than seven	
1.9. Ubudehe categories of the household	01: First category, 02: Second Category, 03: Third category, 04: Fourth Category, 05: Not categorised	
1.10. Do you belong to any livestock keeper's union or association?	01: Yes 02: No	

Section 2: Impacts of climate change and adaptation practices in livestock keeping

2.1. Impacts of climate Change in the region

2.1.1. Do you have any knowledge or information about Climate change?

01. Yes

02. No

2.1.2. If yes, what is the source of your knowledge about Climate change

01. Personnel experience

02. Government officials

03. Schools or training

- 04. Friends/neighbours farmers
- 05. Radio/media
- 06. Parents
- 07. Other specify

2.1.3. How do you perceive the climate change in your region? (more response possible)

- 01. Increased amount of rainfall rainy season
- 02. Decreased amount of rainfall during rainy season
- 03. Increased length of rain season
- 04. Decreased length of rain season
- 05. Early onset of rain days
- 06. Late onset of rain days
- 07. Increase of strong winds events
- 08. Increasing temperature of the area
- 09. Decreasing temperature of the area

2.1.4. Over the last 30 years, have you noticed any long-term changes in weather characteristics?

- 01. Change in mean temperature
- 02. Change in number of hot days
- 03. Change in mean Rainfall
- 04. Long-term shifts in rainfall,
- 05. I don't know/cannot remember.

2.1.5. What was/is the effects of these changes in livestock keeping?

- 01. Decline in livestock productivity (milk, meet, reproduction);
- 02. Decline in forage resources.
- 03. Problem of access to water.
- 04. Restricted livestock mobility.
- 05. Conflict over natural resource use.
- 06. Fluctuations in livestock market prices.
- 07. Animal diseases (emerging and re-emerging)

- 08. Shift in livestock species from cattle to small ruminants
- 09. High mortality in cattle

2.1.6. What was/is the socio-economic impact of climate change effects on your household?

- 01. Loss of income
- 02. Increase expenditure on fodder, water and treatment)
- 03. Failed to cover basic needs (school fees, health insurance etc)
- 04. Failed to payback banks loans
- 05. Failed to pay contributions in Cooperative
- 06. Other (specify).....

2.1.7. How much did it cost you in terms of money (yearly basis compared to the situation there is nothing happened on climate change)?

- 01. Below 50,000 Rwf,
- 02. Between 60, 000 and 200,000 Rwf,
- 03. Between 200,001 and 500,000Rwf,
- 04. Between 500,001 and 1,000,000Rwf,
- 05. Between 1,000,001 and 5,000,000 Rwf,
- 06. Beyond 5, 000,000 Rwf,

2.2. Adaptation Practices

2.2.1. What are indicators used to predict weather conditions?

- 01. Observation of clouds/sky colour and formation
- 02. Unexpected changes of temperature during the day
- 03. Direction and strength of winds,
- 04. Lightning and thunder,
- 05. Other
(specify).....

2.2.2. What is indigenous practice used to cope with prolonged drought or shortage of rainfall?

- 0.1. Farming and grazing along rivers and wetlands
- 0.2. Planting of drought tolerant and early maturing crops
- 0.3. Mulching of farmland
- 0.4. Food reserve in Granary (ibigega)
- 0.5. Reducing livestock herds
- 0.6. Indigenous prayers
- 0.7. Other
(specify).....

...

2.2.3. What is indigenous practice used to cope with climate related pests and diseases?

- 0.1. Use of Locally made pesticides
- 0.2. Burning of pastures and farm residues
- 0.3. Early hand-weeding
- 0.4. Early planting
- 0.5. Use of indigenous medicines
- 0.6. Selection of indigenous crops and livestock breeds
- 0.7. Other
(specify).....

2.2.4. What are indigenous practices used to cope with strong wind events?

- 0.1. Sylivo-Pastoralism and Agro-forestry practices
- 0.2. Use of tree poles to support banana crops
- 0.3. Use of supernatural power
- 0.4. Other
(specify).....

2.2.5. What are indigenous practices used to cope with water shortage?

- 0.1. Rainwater harvesting
- 0.2. Planting of indigenous trees
- 0.3. The use of indigenous wells
- 0.4. Indigenous taboos

0.5. Other
(specify).....

2.2.6. Can you list key challenges of applying indigenous Knowledge?

- 01. Socio-economic transformation
- 02. Poor reputation
- 03. Decrease of the custodians
- 04. Exclusion in the formal adaptation
- 05. Disappearance of indigenous culture
- 06. Vanishing of indigenous seeds
- 07. Other
(specify).....

2.3. Relevance of indigenous knowledge

2.3.1. What are the challenges of applying indigenous knowledge on climate change adaptation (MA)?

- 01. Intrusion of western knowledge*
- 02. Decrease of the custodians of indigenous knowledge*
- 03. Exclusion of indigenous knowledge in the formal adaptation practices*
- 04. Absence of knowledge sharing culture*
- 05. Disappearance of indigenous seeds*
- 06. New generation refuse their use*
- 07. Unevenly distribution of indigenous knowledge*
- 08. Other
(specify).....

2.3.2. Is indigenous knowledge still relevant in climate change assessment and adaptation? (SA)?

- 01. Agree*
- 02. Strongly agree*
- 03. Disagree*
- 04. Strongly disagree*
- 05. I don't now*

2.3.3. What is your preference between Indigenous knowledge and western knowledge (SA)? And why?

01. Indigenous Knowledge
02. New technologies
03. No preference

2.3.4. What is the best way to promote indigenous knowledge in climate change adaptation (MA)?

- 01. Inclusion of indigenous knowledge in the formal adaptation practices*
- 02. Builds on existing practices when developing adaptation technology*
- 03. Replacing western technologies by indigenous knowledge*
- 04. Documentation and awareness on indigenous knowledge*
- 05. Others (specify)*

2.3.5. How do you rate your involvement in design and implementation of adaptation strategy?

01. High
02. Moderate
03. Low
04. Very low

2.4. Assessing vulnerability and Adaptive Capacity of cattle keepers

2.4.1. Is livestock keeping your first source of income?

- 01: Yes,
- 02: No

2.5. If no (in Q.3.1) what is your main income source?

- 01: Growing Crops
- 02: Small Business
- 03: Large business
- 04: Renting households assests (land and house)
- 05: Part time job of household member

06: Full time job of household member

07: Livestock (cattle excluded)

08: Other (Specify)

2.6. What is your monthly average income (in Rwfs: local currency)?

01. Less than 50,000

02. Between 50,001 to 100,000

03. Between 100,001 to 150,000

04. Between 150,001 to 200,000

05. Between 200,001 to 300,000

06. 300,001 and more

Thank you

Appendix 2: Focus Group Discussion guide

- a) List and discuss indigenous practice used to cope with prolonged drought or shortage of rainfall in this region
- b) List and discuss indigenous practice used to cope with climate related pests and diseases
- c) List and discuss indigenous practices used to cope with strong wind events
- d) What are the challenges of applying indigenous knowledge on climate change adaptation?
- e) Is indigenous knowledge still relevant in climate change assessment and adaptation?
- f) What is your preference between Indigenous knowledge and western knowledge? And why?
- g) What is the best way to promote indigenous knowledge in climate change adaptation?
- h) How do you rate local community involvement in design and implementation of adaptation strategy?
- i) What kind of changes (as facts) you have observed in Rwanda over the last 30 years?
- j) Discuss actions under implementation against Climate change impact, and those taken for increasing livestock productivity and their effectiveness

Appendix 3: Interview guide for key informants

- a) How do you rate indigenous Knowledge used to cope with prolonged drought or shortage of rainfall, climate related pests and diseases and strong wind events?
- b) Can you list and discuss key challenges of applying indigenous Knowledge in climate change adaptation?

- c) Do you think indigenous knowledge still relevant in climate change assessment and adaptation?
- d) From your experience and knowledge what is community preference between Indigenous knowledge and western knowledge? And why?
- e) What is the best way to promote indigenous knowledge in climate change adaptation?
- f) How do you rate local community involvement in design and implementation of adaptation strategy?
- g) What kind of changes (as facts) have you observed in in Rwanda over the last 30 years?
- h) What are key effects/impacts of climate change in agro-pastoralism in Umutara Region and in Rwanda in general?
- k) How do you rate the proposed actions against climate change impact and these taken for increasing livestock productivity?
- l) Based on your experience, how best can decision makers incorporate indigenous knowledge into policy, strategy and actions related to climate change adaptation?

Appendix 4: Observation guide

Field observation was conducted through transect walks and participatory observation to document practices reported by respondents. The following approaches were used.

1. Recording Field Data

During transect walks and participatory observation the researcher recorded, managed, and analyzed field observations. The researcher kept a field record, which includes notes, visual records, and Photos.

2. Field Notes

Good descriptive field notes are factual and comprehensive and may capture information about the physical setting, participants, dialogues, activities, and behaviors. Thus, researcher developed an observation protocol to follow in the field and to fill in post-observation. The protocol include relevant details describing each observation. The researcher used descriptive notes to responds answer what, who, when, how questions.

Observation Protocol

Date:	Time:
Duration of the Meeting:	Site:
Participants:	
Event/Action :	
Notes:	
Descriptive:	
Questions :	

Adapted from Johnson, L. Community-based qualitative research (pp. 104-119).

SAGE Publications, Inc, <https://doi.org/10.4135/9781071802809>

3. Photos

In addition to field notes, a researcher will take pictures of the settings and practices. Photographs help document special or unplanned events, such effects of climate changes, adaptation practices or activities causing climate change, degradation of natural resources.

4. Data Management and Analysis

Field observations were systematically analysed in text and written format.

Appendix 5: Visa for data Collection issued by National Institute of Statistics of Rwanda

REPUBLIC OF RWANDA



NATIONAL INSTITUTE OF
STATISTICS OF RWANDA
P.O. Box 6139 Kigali
Tel: +250-788383103 Hotline: 4321
E-mail : info@statistics.gov.rw

Kigali,
15 SEP 2020
N° 0284.../2020/10/NISR

HABAKUBAHO Théogene
Email: habathe2008@gmail.com
Phone: 0788643982

Dear Sir,

RE: Visa Approval

Reference is made to your letter dated August 26th, 2020 requesting for authorization to conduct the study on "*Contribution of Traditional Knowledge to Climate change Adaptation (Umutara Region in Rwanda*" in Nyagatare and Gatsibo districts) from 21st September to 21st October, 2020.

After examining your request and according to the law N° 45/2013 of 16/06/2013 stating on organization of statistical activities in Rwanda, we have the pleasure to inform you that the visa has been granted, with the conditions that the data and final report will be submitted to NISR before publication. In addition, since the survey data collection will be conducted during the Covid-19 crisis, interviews have to be done by respecting the guidelines stated by the Ministry of Health such as wearing the face masks, hand washing and respecting at least one-meter distance between two persons.

Details of the visa are attached

Thank you for your collaboration

MURANGWA Yusuf
Director General



Website : <http://www.statistics.gov.rw>

Appendix 6: Clearance for data collection issued by the Open University of Tanzania

THE OPEN UNIVERSITY OF TANZANIA DIRECTORATE OF POSTGRADUATE STUDIES

P.O. Box 23409
Dar es Salaam, Tanzania
<http://www.openuniversity.ac.tz>



Tel: 255-22-2668992/2668445
ext.2101
Fax: 255-22-2668759
E-mail: dpgs@out.ac.tz

Our Ref: PG2017011588

18th February 2020

Mayor,
Gatsibo District,
Eastern Province,
KIGALI-RWANDA.

RE: RESEARCH CLEARANCE

The Open University of Tanzania was established by an Act of Parliament No. 17 of 1992, which became operational on the 1st March 1993 by public notice No.55 in the official Gazette. The Act was however replaced by the Open University of Tanzania Charter of 2005, which became operational on 1st January 2007. In line with the Charter, the Open University of Tanzania mission is to generate and apply knowledge through research.

To facilitate and to simplify research process therefore, the act empowers the Vice Chancellor of the Open University of Tanzania to issue research clearance, on behalf of the Government of Tanzania and Tanzania Commission for Science and Technology, to both its staff and students who are doing research in Tanzania. With this brief background, the purpose of this letter is to introduce to you **Mr.HABAKUBAHO, Théogène Reg No: PG2017011588** pursuing PhD in **Environmental Studies**.

We here by grant this clearance to conduct a research titled *Contribution of Traditional Knowledge to Climate Change Adaptation: A Case of Livestock Keeping in Umutara Region in Rwanda*. He will collect his data at your area from 15th February 2020 to 30th June 2020.

In case you need any further information, kindly do not hesitate to contact the Deputy Vice Chancellor (Academic) of the Open University of Tanzania, P.O.Box 23409, Dar es Salaam. Tel: 022-2-2668820. We lastly thank you in advance for your assumed cooperation and facilitation of this research academic activity.

Yours Sincerely,

Prof. Hossea Rwegoshora
For: VICE CHANCELLOR
THE OPEN UNIVERSITY OF TANZANIA

Appendix 7: Statement of consent

Good morning. Thank to give your time for this interview. My name is
 I am
 conducting scientific research title " Contribution of indigenous knowledge to
 climate change adaptation: a case of livestock keeping in Umutara region, Rwanda.
 This research is conducted to fulfil requirement of PhD program offered by the Open
 University of Tanzania and is aiming at contributing to the enhancement of resilience
 of cattle keepers in your region.

For the above reason, we want to collect information about current challenges,
 practices and opportunities related to the adaptation to climate change among cattle
 keepers. The accuracy and correctness of information provided will be very useful in
 designing appropriate mitigation measures. We assure you that results from this
 survey will be only used for research purposes and your personnel information will
 not be disclosed. You have the right to accept or to refuse and if you refuse, you
 don't break any law.

If you accept, please fill this form and sign.

Respondent Name:

Phone:

Date:

Signature:

Surveyor name:

Phone:

Date:

Signature: