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Agricultural vulnerability to changing rainfall patterns: Assessing the role of smallholder farmers' perceptions and access to weather forecast information in adaptation-decision making

– Case study of the North-Western provinces, Rwanda

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Cover picture: Picture showing the sustainable farming practices on a hilly landscape in Mukamira Sector, Nyabihu District (photo: Didier Muyiramye)

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Abstract

Adverse weather is currently among the crucial challenges facing agricultural development in sub-Saharan Africa. With climate change and variability increasing, rainy seasons are becoming more and more unpredictable. Heavy rainfalls and severe flooding have increased, affecting smallholder farming and rural livelihoods considerably. Using qualitative and quantitative methods in data collection, this study aimed at exploring climate change adaptation strategies in North-Western Rwanda, by assessing the role of smallholder farmers' perceptions on the vulnerability of their farming to changing rainfall patterns, while also analysing the factors influencing the adoption and use of weather forecast information in adaptation-decision-making. I used two different theoretical approaches to analyse the research questions: The ''Protection Motivation Theory'' to study how smallholder farmers' perceptions on the farming vulnerability to changing rainfall patterns shape coping mechanisms and adaptive strategies, and the ''Diffusion of Innovations'' theory to investigate the role of weather forecast information in adaption-decision making. Results indicated that a high level of awareness of climate threats, of the causes of climate change and coping measures, can be important drivers of the adaptation decisions that can contribute to a well-timed anticipation and preparedness against climate threats. The results also suggest that the adoption and use of weather forecast information in farm-decision making depend much on the accuracy and content of information, communication channels, farmers' digital literacy and forecast skills. The study recommends that the formulation of better adaptation strategies should base their interventions on farmers' perceptions and knowledge and integrate it with the weather forecast information.

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Keywords: Vulnerability, Perception, Weather forecast information, Changing rainfall patterns, Heavy rainfalls, Floods, Smallholder Farmers, Adaptation

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I apologize if I have forgotten anyone.

Table of contents

List of tables

List of figures

Abbreviations

CIAT	International Center for Tropical Agriculture
DERN	Programme pour le développement Rural du Nord
DOI	Diffusion of Innovation
DRC	Democratic Republic of Congo
FECOPORWA	Fédération des Coopératives des producteurs de pomme de terre au Rwanda
FGD	Focus Group Discussion
GDP	Gross Domestic Product
IFAD	International Fund for Agricultural Development
IRI	International Research Institute for Climate and Society
IIRR	International Institute for Rural Reconstruction
KIT	Royal Tropical Institute
MAM	March-April-May
MIDIMAR	Ministry of Disaster Management
MINAGRI	Ministry of Agriculture and Animal Resources
MINEMA	Ministry of Emergency Management
NCOF	National Climate Outreach Forum
NCEA	Netherlands Commission for Environmental Assessment
ND-GAIN	Notre Dame Global Adaptation Index
PASP	Post-Harvest and Agri-Business Support Project
PICSA	Participatory Integrated Climate Services for Agriculture
PMT	Protection Motivation Theory
RAB	Rwanda Agriculture Board
RCSA	Rwanda Climate Services for Agriculture
REMA	Rwanda Environment Management Authority
RMA	Rwanda Meteorological Agency
RTI	International Research Triangle Institute
RWFA	Rwandan Water and Forestry Authority
SEI	Swedish Environmental Institute
SMS	Short Message Service
SOND	September-October-November-December
UNDP	United Nations Development Programme

UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USSD	Unstructured Supplementary Service Data

1. INTRODUCTION

Around the world, climate change continues to impose significant socio-economic impacts on agriculture. It has changed the prediction schemes, making it more and more difficult to make precise predictions (Zhu *et al.* 2011). Agriculture which is the backbone of economy in many developing countries and is dominated by small-scale and subsistence farming, continues to be exposed and vulnerable to climate extremes (Field *et al.* 2012). In tropical regions, smallholder farmers face food insecurity due to numerous risks, including pest and disease outbreaks, severe weather events and market shocks, to cite a few, which all have a negative effect on smallholder agricultural production (Harvey *et al.* 2014).

Generally, rainfall which is critical to agriculture is more difficult to predict than temperatures (Zhu *et al.* 2011). The variation of seasonal cycle of rainfalls is therefore of great significance to African agriculture (Dunning *et al.* 2016). Due to rainfall changes, growing seasons are expected to continuously change which will decrease the agricultural productivity, particularly in Africa (Zhu *et al.* 2011). The changes of onset and cessation dates of rainy seasons also affect the life cycle of the disease transmission vectors, which is sensitive to variability and changes in temperature and rainfall - (Amekudzi *et al.* 2015).

On one hand, the design of adaptation strategies is hampered by a lack of basing interventions on farmers' perceptions about climate change, and this results into an ineffective risk communication (Eitzinger *et al.* 2018). Several studies have been conducted on climate change, unfortunately only a few touched upon the perception of vulnerability to climate change (Hasan & Kumar 2019). This is challenging as before reacting to climate change, one must perceive climate change (ibid). Adaptation measures are greatly influenced by farmers' beliefs and perceptions on the causes and impacts of climate change (Eitzinger *et al.* 2018). For instance, some studies revealed that apart from a rich evidence brought by scientific findings, the local knowledge of farmers, including cultural, religious dimensions that have been used for a long time in climate prediction, play a role in adaptation and should not be ignored (Kuivanen *et al.* 2015).

On the other hand, since rainfall is very critical to farming, there is a growing need of weather forecasts (Oyekale 2015) in a changing climate. Accurate seasonal forecasting is indispensable for African smallholder farmers (Chisadza *et al.* 2020). Research findings have shown that weather forecasts can be useful in reducing the vulnerability of rain-fed farming to flooding, droughts and extremely low or high temperatures (Oyekale 2015). There are several initiatives across Africa providing weather forecast services to reduce agricultural losses resulting from extreme weathers, but at the same time there are also many challenges with regards to information accessibility and utilization (Oyekale 2015). Communication is a key aspect in the successful adoption and use of seasonal forecast information technology (Zhu *et al.* 2011). Other challenges impeding the utility and uptake of weather forecasts, particularly the seasonal forecast information, are tied with technological, societal and interdisciplinary levels (Chisadza *et al.* 2020).

1.1. Research problem

In Rwanda, a country that depends mostly on agriculture, climate change continues to cause increased climatic hazards which affect rural smallholder farming considerably. ‘’An analysis of rainfall trends has shown that rainy seasons are becoming shorter and more intense, especially in the northern and western provinces, which increases erosion risks in the mountainous region of the country (NCEA 2015)’’. The high vulnerability is caused by a wide range of natural hazards such as floods, flash floods, landslides/mudslides, drought, storms, lightning, earthquake, volcanic eruption, fires and epidemics (UNDP & MIDIMAR 2013) and heavy rainfalls. However floods and landslides emerge as the main disasters, especially in the North Western high altitude regions (REMA 2009). These weather hazards, most of the times triggered by heavy rainfalls, ceaselessly cause huge human and socioeconomic losses. Between 2011 and 2013, landslide events resulted into 74 deaths, 22 injuries, 573 houses destroyed and 656 ha of affected land (Dalena *et al.* 2015).

To tackle the problem, reduce the risks and enhance climate resilience, the government of Rwanda together with other development partners design and execute disaster risk management projects in rural areas prone to environmental degradation. One of the six priority areas for climate change adaptation identified by involved stakeholders is setting up an information system for early warning of hydrological and agro-meteorological systems and rapid intervention mechanisms (REMA 2009).

Unfortunately there is a lack of trust by farmers in the given information system. There are requests for a system which can better disseminate the weather forecast and early information, according to farmer needs. Coulibaly (2017a) indicated that a lack of trust in the information and a lack of locally relevant climate information slow down the adoption of the weather forecast information. Huge socio-economic losses will continue to affect negatively smallholder farmers' livelihoods, unless the provision of timely and accurate weather forecast, and early warning information becomes adequate. This will result into better preparedness and better farming decision-making and contribute significantly to reducing the vulnerability and increasing resilience to heavy rains, floods and landslides.

1.2. Purpose of the study and research questions

The purpose of this study was to investigate farmers' perceptions on farming vulnerability to changing rainfall patterns, and to study the role of weather forecast information in adaptation decision-making. In particular this study aimed to**:**

- Examine if farmers understand the causes of climate change and the impacts of changing rainfall patterns on their farming.
- Analyze the nature and sources of vulnerability of smallholder farming to changing rainfall patterns.
- Explore farmers' perceptions on the vulnerability of their farming and their abilities in coping with changing rainfall patterns.
- Investigate the correlation between farmers' perceptions on the vulnerability of their farming to changing rainfall patterns, and the adaptation systems / practices.
- Study at what extent do farmers use the weather forecast information in their farming decision-making to reduce the impact of changing rainfall patterns.
- Identify constraints limiting farmers in adopting and using weather forecast information.

1.3. Thesis Outline

The thesis is subdivided into seven chapters. The first chapter consists of an introduction and research questions. The second chapter focused on reviewing the existing literature that covered the topics of smallholder farming vulnerability to impacts of climate change and variability. Chapter three focuses on methodology, describing the study area and methods of data collection. Chapter four discusses the theories and concepts. Chapter five is the main body of the thesis that present the empirical findings. Chapter six discusses how farmers' perceptions on the vulnerability of their farms, the coping measures taken against the changing rainfall hazards, and the influence of farmers' awareness and understanding of climate change and variability. Chapter seven gives conclusion and policy implications.

2. REVIEW OF LITERATURE

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as: “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods ” (Field *et al.* 2012). UNFCC also indicates that climate change is attributable to human activities that disturb the atmospheric conditions, whereas climate variability can either be part of climate change or attributable to natural causes (ibid). However other studies highlight that climate change and climate variability are both characterized by variations in the mean state of climatic conditions (such as the occurrence of extremes), with the only difference being that the changes are long-term for climate change and short-term for climate variability (Mudombi 2014). WMO also indicates that climate variability looks at changes of the climate within shorter timeframes (a month, season or a year), while climate change takes into consideration changes over a longer period of time like decades (WMO).

Over recent years, vulnerability, adaptation, and adaptive capacity have emerged as key concepts to explore when assessing the societal implications of climate change (Kuivanen *et al.* 2015). Climate change contributes to vulnerability by increasing uncertainty and unpredictability in the environment, worsening the livelihoods of poor people (Zhu *et al.* 2011). On one hand, increased precipitations are some of the climate change impacts, that are affecting agricultural production in large parts of Latin America, Asia and Africa (Zhu *et al.* 2011). On the other hand, the unreliability of weather patterns and traditional indicators, increases the vulnerability of farming production losses as a result of unpredicted weather events like heavy rains that wash away seedlings (ibid).

2.1. Characteristics of the climate and landscape in Rwanda

2.1.1. Rwanda Climate and Seasonal Changes

Rwanda has a temperate climate, diversified across the country, according to different topographical variations: temperatures and rainfalls are influenced by mountains, valleys and low-lying areas (ENTREM & RTI International 2019). However, although there is a good distribution of the rainfall throughout the year, there are some irregularities across regions (Mikova *et al.* 2015). The mountainous region in the north-western Rwanda is cooler and wetter, whereas the low-elevated eastern part is warmer and drier (ENTREM & RTI International 2019). The eastern and Southern regions are often vulnerable to prolonged droughts, whereas the northern and western regions are usually affected by excessive rainfall that cause erosion, flooding and landslides (Mikova *et al.* 2015). The average annual temperature is 15-17C in high altitude and around 30C in the dry lowlands of the East and Southwest (NCEA 2015). The weather in Rwanda is highly characterized by an alternation of two dry seasons and two wet seasons two rainy seasons: the long rainy season from March to May, and the short rainy season from September to December, however, the global and regional weather systems often result into distinct contrasts of rainfalls between years (ENTREM & RTI International 2019). The average annual rainfall is about 1,250 mm per annum (Dalena *et al.* 2015), but varies between 700 mm and 1,600 mm (*Rwanda Country Situational Analysis: Compiled by Alphonse Mutabazi Climate Change Consultant for Camco, Nairobi, Kenya*, 2011).

2.1.2. Hydrological and topographical factors

Two major drainage sub-catchments divide the country's drainage system: The Nile to the east representing 67% and the Congo to the West (ENTREM & RTI International 2019). A range of mountains (2500 – 3000m) commonly known as ''Congo-Nile crest'', dominated in the North West by volcanoes, separate the two sub-catchments. Due to the over-exploitation of steep hills and intense rainfalls, the topography and local climate of this volcanic region are highly vulnerable to climate change, resulting into run-off, erosion and flooding (ibid).

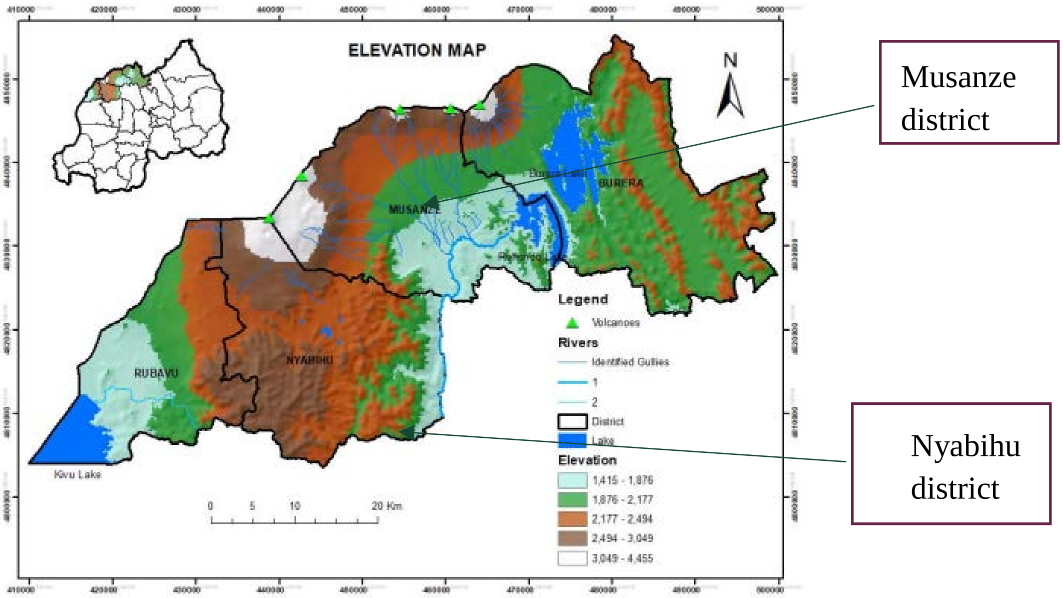

Figure 1: Topographical characteristics of the North-Western Rwanda. Adapted from (ENTREM & RTI International 2019).

2.2. Rwanda Vulnerability to Climate Change

The measures of the country's vulnerability to climate change, show that Rwanda ranks 116th out of 178 countries on ND-GAIN Index (2016). Vulnerability is defined as the tendency or predisposition of a human or natural system to be disturbed by climate change (Ricart *et al.* 2018) or as the susceptibility of a community, system or asset to experience damaging effects of a hazard (Dalena *et al.* 2015). It involves three main aspects: exposure to hazard, sensitivity to damage and coping abilities (ibid). The vulnerability of Rwanda to weather hazards involves both environmental and socio-economic factors. On one hand, the vulnerability is largely due to its topographic and demographic characteristics. Known as "the land of a thousand hills", Rwanda's landscapes are on a high elevation, with a mountainous and hilly relief, five volcanoes, twenty-three lakes throughout the country and many rivers, which meet to form the source of the River Nile (UNDP & MIDIMAR 2013). On the other hand, the socio-economic vulnerability is another factor. The problem is aggravated by the fact that Rwanda strongly depends on agriculture at a level of 90% of the population (directly or indirectly employed by agriculture) living in poor livelihoods. Another challenge increasing the vulnerability, is Rwanda's strong dependency on natural resources: ''an evaluation of social vulnerability to climate change ranks Rwanda first among all African countries in terms of natural resource dependency, which it considers to be one of three indicators for social vulnerability to climate change (NCEA 2015)''.

2.2.1. Vulnerability of smallholder agriculture to climate change

In Rwanda, the agricultural sector which is among the biggest engines of the country's economy, contributing 30.96% of the national GDP (Plecher 2019), is largely rain-fed and still practiced on a small-scale, with 84% of household farming practiced on less than 0.9 hectares of land (Dalena *et al.* 2015). Unfortunately, it continues to be vulnerable and threatened by rising temperatures, frequent heavy intense rainfalls and increased dry spells (USAID 2019).

An increasing rainfall intensity often results into flooding and landslide hazards, which take human lives and damage crops and infrastructure (ENTREM & RTI International 2019), and strongly affect people with less efficient coping mechanisms (Nsengiyumva 2012). The vulnerability of agriculture to floods and landslides is more intense in the Northern Province due to a mixture of landscape (Nsengiyumva 2012). According to Stockholm Environment Institute (2009), major flood events occurred in 1997, 2006, 2007, 2008, and 2009, resulting in infrastructure damage, fatalities and injuries, landslides, agricultural crops losses and damages, soil erosion and environmental degradation. Among different types of floods, flash floods and riverine floods are the most frequent (Dalena *et al.* 2015). Riverline floods happen when the flooding of the rivers occurs outside its regular boundaries, whereas flash floods happen when local rain falls within a short period of time, resulting in the rising of water levels (Dalena *et al.* 2015). Flash floods on steep slopes cause soil erosion washing it away down the slopes (Nsengiyumva 2012). However, even though heavy rains do contribute to the soil erosion risks and degradation of arable lands, their contribution is only an indirect cause. Soil erosion on steeply sloping are mostly attributable to the lack of soil conservation practices e.g. soil and water management, restoration of organic matter and avoidance of exploitation (Pavageau *et al.* 2013), and affects at least 50% of all farmers, resulting in a 30% reduction of farm productivity (*Rwanda Country Situational Analysis: Compiled by Alphonse Mutabazi Climate Change Consultant for Camco, Nairobi, Kenya*, 2011). Similarly, landslides in Rwanda are among the deadly natural hazards that are continuously destroying roads, affecting food transportation. Between 2011 and 2013, landslide events resulted into 74 deaths, 22 injuries, 573 houses destroyed and 656 ha of affected land (Dalena *et al.* 2015).

Climate change also affects negatively the seasonal agriculture, in a way that even small changes in precipitations can significantly disrupt the agricultural production (Ntirenganya 2016). The starting date of a rainy season is therefore very critical to the planning of agricultural seasons, particularly for planting (Meteo Rwanda 2020). In 2017, The Rwandan Ministry of Environment reported an increasing variability in the rainfall intensity, as well as changes on the timing, onset and cessation of rainy seasons. Farmers indicate the extension of the onset of the rains from March to June (which was previously from April to June) and a late cessation of rains from November to January (contrarily to November to December, in the past) as major changes in seasonal patterns (NCEA 2015). Rainy seasons are becoming shorter and intense, increasing erosion risks especially in the North-Western areas of the country (ibid) leading to heavy leaching of soil nutrients, mineral content and organic matter (ENTREM & RTI International 2019).

Projected climate change effects in Rwanda indicate that by the 2050s, the future climatic conditions are projected to be characterized by increased heavy rainfall events with 7-40 percent of frequency and 2-11 percent intensity (USAID 2019). This rainfall is expected to change between -100 mm and +400 mm for the period 2000-2050 (NCEA 2015) with the average annual rainfall raising by up to 5-10% by the 2030s from 1970 (REMA 2015). The climate change impacts on agriculture will also include increased risks from pest and diseases, crop loss / land degradation (USAID 2019), and soil and nutrient loss, thus challenging agricultural growth (Republic of Rwanda 2018).

2.3. Adaptation to Climate change

In the context of climate change, adaptation is defined as ‘’the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate’’ (Field *et al.* 2012). Two stages are involved in the process of adaptation to climate change: to first perceive the change, and then take decisions on whether to adopt and/or put into action a particular measure (Mudombi 2014). To develop a certain attitude towards a climate issue, requires accessing information first, therefore only the farmers who perceive climate will develop a need of adaptation (ibid). It is therefore important for farmers to be aware of existing climate solutions and understand that they can a play a key role to play in the implementation of those solutions.

Awareness and information access are therefore among the key criteria for prioritization of adaptation technologies (Zhu *et al.* 2011). Availability of information from climate monitoring systems, as well as the local weather forecast knowledge from the community, is vital to designing suitable technologies enabling adaptation to climate change (Zhu *et al.* 2011). An effective adaptation requires a smooth collaboration between the providers and users of climate information (Zhu *et al.* 2011).

2.3.1. The importance of understanding farmers' perception

Several studies have been conducted on climate change, unfortunately only a few touched upon the perception of vulnerability to climate change (Hasan & Kumar 2019). This is challenging as before reacting to climate change, one must perceive climate change (ibid). Therefore, to effectively design and implementation adaptation strategies, we have to understand the individual farmers' perceptions of climate change and vulnerability, and their influence on their decision-making (Eitzinger *et al.* 2018). Small-scale farmers should first visualize climate change as one of the multiple exposures, otherwise they will not adapt their farming practices, even if suggested by climate policies (ibid). The fact that several studies carried out in sub-Saharan countries revealed contrasting perspectives between farmers' perceptions of changes and the observed precipitations (Kosmowski *et al.* 2017) also pushes to explore and take into consideration the local understandings in adaptation measures.

2.3.2. The role of Weather Forecast Information

Access and use of weather forecast and early warning information is among the adaptation practices or technologies that facilitate risk management of adverse weather hazards (SEI 2009). Accurate climate data are indispensable in ensuring the monitoring of climate change impacts and vulnerability at global, regional and national levels (Kadi *et al.* 2011). To monitor weather and climate changes, the forecast information is obtained through a process of integrating satellite observations, ground-based data and forecasting models (Zhu *et al.* 2011), with a combination of statistical analysis using historical records. The weather and climate information should explain the involved uncertainty of future impacts and should be designed according to the demand of users and in a format easily understandable by everyone (ibid).

Setting up an information system for early warning of hydrological and agro-meteorological systems and rapid intervention mechanisms, is one of the six priority areas identified by REMA for adaptation to climate change and disaster risk management (REMA 2009). Numerous responsible institutions work hand in hand to ensure an efficient provision of up to date, timely and accurate meteorological information (Nahayo *et al.* 2017). RMA oversees the production, analysis and forecasting of the weather and climate information, whereas the Ministry of Disaster Management coordinates activities linked with the management of natural disasters (Coulibaly *et al.* 2017a). An initiative named "Enhancing National Climate Services Initiative (ENACTS)" is led by The International Research Institute for Climate and Society (IRI) and partners. It operates with the aim of improving the availability, access and use of climate information in African countries (Republic of Rwanda 2018). This is done through an exercise of controlling the quality of weather station data as well as generating historical data done by a process of combining station observations with satellite data (ibid). RMA also implemented this approach by generating over 30 years (1981 to present) and 50 years (1961-2014) of rainfall and temperature time series respectively (Republic of Rwanda 2018).

There are several types of climate information: these include daily weather forecasts, monthly climate outlooks, seasonal climate outlooks, early warning alerts (Kadi *et al.* 2011). Generally, seasonal forecast information is the type of climate information that is the most needed by farmers (ibid). Unfortunately smallholder farmers fail to integrate the seasonal climate forecasts into their farm planning, due to numerous limitations including the lack of forecast skill, lack of communication and the incapacity to realize its relevance in farming decision-making (Chisadza *et al.* 2020). On one hand, making the climate information relevant as well as ensuring its successful reach to all farmers, remains problematic (Zhu *et al.* 2011). The constraints preventing farmers in both accessing and using climate information are many. Firstly, accessibility of information depends on communication channels. In a study carried out in Rwanda by Coulibaly *et al*. (2017a), results showed that radio emerges as the main communication channel of meteorological information used by 74% of interviewed farmers, followed by government extension agents, neighbors and farmer-to-farmer communication. The same study found out that despite the ownership of cell phones by many farmers, the dissemination of climate information on cell phones was almost non-existent (Coulibaly *et al.* 2017a). Also the awareness of the climate information by farmers is still low: less than one third seek climate information (Coulibaly *et al.* 2017b). Additionally, it was found that women are generally less aware of the availability of climate information than men (Coulibaly *et al.* 2017a), a gap that can be attributable to the fact that women are far behind men, with regards to ownership of communication assets and participation in social groups (Nsengiyumva *et al.* 2018a). Secondly, a lack of trust from the farmers towards to the climate information provided, as well as the low relevance of information to a local context, limits the influence of climate information on farmer decision-making and behavioral change (Coulibaly *et al.* 2017a). Due to these contexts, poor and remote communities continue to be more vulnerable to climate change, due to their inability (or less ability) to access relevant climate and early warning information (Zhu *et al.* 2011). Such communities prefer to rely on traditional forecasting methodologies, which include local observations of climatic and other environmental changes like animal behaviors (mating and migration conditions), changes in plants (flowering of certain trees or hydrological tolerance), and weather patterns (status of dry and cold periods) (Zhu *et al.* 2011). However, traditional forecasting is currently also challenged by climate change: using natural indicators to make weather predictions is no more reliable due to changes in the climate, farmers therefore are seeking for the new climate information.

3. CONCEPTS AND THEORIES

I combine Protection Motivation Theory and Diffusion of Innovations theories, to assess farmers' perceptions on the farming vulnerability to climate change and changing rainfall patterns, as well as investigating the role of weather forecast information in adaptation-decision making.

3.1.1. Protection Motivation Theory

Protection Motivation Theory (PMT) was developed by R.W. Rogers in 1975 and was originally designed targeting health threats but it has shown a high potential of applicability in other sectors' threats, including natural and technological hazards (Grothmann & Reusswig 2006) – earthquake in the United States of America, flooding hazards in Germany and France, and climate change adaptation programs (Westcott *et al.* 2017). The main objective of PMT is to detect and assess the danger, and then come up with effective risk reduction measures (ibid).

The PMT builds its idea on the Threat appraisal and Coping Appraisal as two major perceptual processes dictating how a person responds to the threat and driving the self-preservation behaviour (Birkholz *et al.* 2014): *Threat appraisa*l (risk perception or the likeliness and severity of a potential threat) and *coping appraisal* (how likely is the person's ability to cope with the threat).

On one hand, the *Threat Appraisal* includes two major sub-components (Grothmann & Reusswig 2006):

- The *Perceived Probability* of a threat (the person's perception of being exposed to a certain risk which will harm him/her and/or his/her belongings, i.e their *Vulnerability*).
- The *Perceived Severity* of threat (or in other terms, a person's perception on the harmfulness of the threat on his/her property and other valuable things).

Some other authors like Grothmann & Reusswig (2006) added *Fear* as a third element, aggravating the individuals' perceptions on the severity of a certain threat

On the other hand, the *Coping Appraisal* has three sub-components(Grothmann & Reusswig 2006):

- The perceived response-efficacy of recommendations, which entails the person's belief that the recommended actions will effectively eliminate the danger (Cismaru *et al.* 2011).
- The perceived self-efficacy or a person's belief that he or she is able to effectively adopt the recommended actions (Cismaru *et al.* 2011).
- The perceived costs of recommendations, representing the barriers that prevent people to engage in the recommended behavior, and include both monetary and non-monetary costs such as time, effort, discomfort and inconvenience

As an expansion of the PMT, (Westcott *et al.* 2017) also evoked the role of *Trust* and *Uncertainty* as critical elements affecting the coping appraisals. Trust in agencies delivering emergency information, trust in the emergency services and trust in self-capabilities of appropriate response in case of a certain threat (ibid). Uncertainty is a factor pushing the community to come together to find solutions in how to cope and mitigate hazards. To counterbalance the risk perceptions brought by uncertainty, (Westcott *et al.* 2017) argue that whenever uncertainty increases, trust in the sources of information should also be increased.

The Threat and Coping appraisal processes influence people's behavior change and directs their actions to protect themselves, leading to either protective or non-protective responses (Bubeck *et al.* 2013). Protective responses are those actions that actually lead to reduce threats, protect monetary or physical damage (Grothmann & Reusswig 2006) and are taken if high threat appraisals are associated with high coping perceptions. Non-protective measure include denials of threat, wishful thinking and fatalism and do not prevent monetary or physical damage, but rather generates negative emotional perceptions of threat severity, or fear (Grothmann & Reusswig 2006). People take non-protective measures when their threat appraisal is high and their coping appraisals low.

Choosing a protective measure leads to a decision or intention to take action, called protection motivation, which doesn't always translate into actual behavior due to barriers like lack of time, money, knowledge (Grothmann & Reusswig 2006).

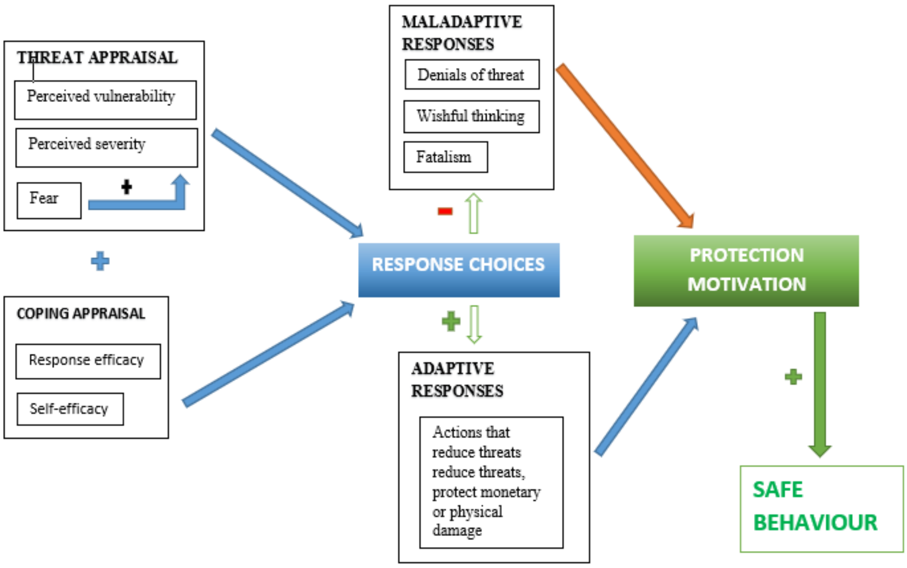

Figure 2: Expansion of the conceptual of Protection Motivation Theory (Adapted from Westcott et al. 2017).

3.2. Diffusion of Innovation

The Diffusion of Innovation (DOI) is among the oldest social theories, it was first introduced by Roger Everett in 1962. In this theory, Rogers (1983) explains how getting a new idea adopted, even if it has advantages, is always difficult. If a new innovation is easy to understand, its target people will adopt it, however it is constrained by numerous factors, e.g. cultural, traditional, local knowledge, uncertainty and past experiences with the innovation. Some will prefer to not adopt the new technological innovation, and rather rely on the old innovation (ibid).

(Rogers 1983) defines diffusion as a process by which an innovation is communicated through certain channels over time among members of a social system. He argues that a certain type of communication is involved in diffusion, where two individuals exchange information in the form of a new idea. DOI theory is built on a consideration of aspects of innovation (or new technology), the communication approach, adoption decision-making process and the social conditions.

3.2.1. Innovation

Rogers defines innovation as ‘’an idea, practice, or object that is perceived as new by an individual or other unit of adoption’’ (Rogers 1983). The reaction of an individual to an innovation is conditioned by how he/she perceives the newness of that idea. If the idea seems new to the individual, it is an innovation. In this theory, Roger interchangeably used the terms ‘’innovation’’ and ‘’technology’’ with the same meaning.

According to (Rogers 1983) there are 5 key elements that characterize how users will respond (adopt or reject) to an innovation: relative advantage, compatibility, complexity, trialability and observability

- Relative advantage: This is described as the degree to which an innovation is perceived by users as better or more advantageous than the idea it supersedes. It is measured by other sub-dimensions like economic profitability, social prestige factors, convenience and satisfaction.
- Compatibility: defined as how much the philosophy of the new technology is compatible with existing culture, values, past experiences and needs of potential adopters. For an innovation to be adopted successfully, it should meet the needs of adopters, not be in contrast with the society’s beliefs.
- Complexity: The degree to which an innovation is perceived as easy to understand and use. Here, either the knowledge of adopters or the simplicity of an innovation plays a key role in determining whether or not an innovation will be more likely to be adopted.
- Trialability: Rogers defines trialability as the degree to which an innovation can be trialed. Before putting into action, an innovation should be tested on a certain group of people from the social system to explore the possibilities of a logical implementation.
- Observability: The degree to which the results of an innovation are visible to others. The more the results can be seen by individuals, the greater there is chance to be adopted.

Rogers also evoked ‘’uncertainty’’ as an important obstruction to the innovation adoption implying a lack of predictability of the future (Rogers 1983). A certain degree of ‘’uncertainty’’ lies in the newness of the new idea (innovation) and affects the innovation adoption process of the social system. On one hand, uncertainty is constructed by innovation’s consequences, therefore it is important to study and inform individuals on the advantages and disadvantages of an innovation, to make them aware of potential consequences (Sahin 2006). In fact, as he states, an informative aspect of every technology/innovation should be based on reducing the uncertainty for individuals (Rogers 1983).

One the other hand, a technological innovation in itself presents a certain form of uncertainty. An innovation always comes to the individual or organization with new alternatives and/or suggesting changing practices. The fact of suggesting an innovation as being better than previous practices will create a certain doubt in the individuals and push them to seek for further information, in an attempt to eliminate the uncertainty that it creates. Generally, the more uncertain innovation potential users are, the less there is a possibility of adopting the technology.

In the discussion part of this research, I will discuss farmers' perceptions towards the received weather forecast information in relation with the above characteristics of an innovation.

3.2.2. Communication

According to (Rogers 1983), communication is the ''process by which participants create and share information with one another in order to reach a mutual understanding''. Diffusion in itself is a type of communication involving an exchange of information consisting of new ideas. Rogers (1983) says that information communication requires four important elements: (1) an innovation, (2) an individual or other unit of adoption that is knowledgeable in operating the innovation, (3) an individual or other unit of adoption that is not knowledgeable of the innovation, and (4) the communication channel linking the two units.

Rogers (1983) considers mass media channels and interpersonal communication as two main communication channels:

- Mass media channels: On one hand Rogers (1983) recognised mass media channels (radio, television, newspapers) as rapid and efficient channels in conveying information from a source of one or few individuals to a bigger audience of potential adopters. On these mass media channels was added later on internet, which emerged as the most flexible medium in rural and agricultural development (Richardson 1997). In 1996, only 6 African countries did not have internet (ibid)

- One the other hand, interpersonal channels involve face-to-face exchange of information between two or more individuals. Rogers explains that this type of information is more efficient in persuading individuals to adopt an innovation, especially when there is a high degree of resemblance between the transmitter and the recipient of information

Interpersonal communication may take different forms including homophily and heterophily. Homophily is defined as ‘’the degree to which pairs of individuals who interact are similar in certain attributes, such as beliefs, education, social status, and the like’’ (Rogers 1983). It builds its assumption on the fact that communication is much effectively easier and will generate more knowledge gain, attitude and behaviour change, for individuals who share common meanings, language, and are alike in personal and social characteristics. However Rogers (1983) states that homophily can act as a barrier to diffusion: If individuals are identical in terms of their knowledge about an innovation, diffusion can be difficult because there will be no new information to exchange. New ideas generally enter a system through individuals of higher status with a greater capacity of capturing quickly innovation.

Roger therefore argues that a certain degree of heterophily between two individuals, is needed for the diffusion of innovations. Heterophily being defined as “the degree to which two or more individuals interact are different in certain attributes’’ (Rogers 1983). Ideally individuals should be homophilous on aspects like education and social status, but heterophilous regarding innovation. Generally, individuals seek interactions and network links with who are slightly, but not too much, more knowledgeable about innovation than themselves (ibid).

3.2.3. Time

The third element of diffusion is time. (Rogers 1983) argues that in most behavioral science research, time is often ignored but that it is normally a very important element to consider when you are studying diffusion of innovations in the society.

3.2.3.1. <u>Innovation-decision process</u>

Diffusing an innovation requires communicating information to potential adopters who have to go through a number of steps over time, to fully adopt and make decisions based on it. Rogers (1983) explains that the innovation-decision process involves 5 steps:

- <u>Knowledge</u>: This occurs when an individual gets to know first that a certain innovation exists and gains an initial understanding of how it functions. At this stage, the main objective is to seek a software information embodied within a technological innovation, to reduce uncertainty. The individual wants to know what the innovation is, and how and why it works.

- Persuasion: an individual or other unit of adoption, is persuaded of the advantages of an innovation, and develops a favourable attitude towards it. At this stage the individual seeks innovation-evaluation information that will help understanding how relevant the innovation is to his or her own situation. This means assessing the advantages and/or disadvantages that the innovation may present to his/her work. It is this subjective evaluation that will influence whether or not the individual takes the decision to adopt an innovation
- Decision: an individual or other unit of adoption engages in activities that will lead to the adoption or rejection of the innovation.
- Implementation: an individual or other unit of adoption starts to put an innovation into use
- Confirmation: happens when an individual or other unit of adoption seeks reinforcement about the innovation decision (e.g.: discussion with peers). This means evaluating changes resulted from innovation-based decisions made.

3.2.3.2. Innovativeness and adopter categories

Roger argues that individuals go through the innovation-decision process at different rates. He therefore classifies five adopter categories basing on the innovativeness. Innovativeness is defined as ''the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than the other members of the system'' (Rogers 1983). The five adopter categories are:

- Innovators (*Venturesome*): These are people that are always seeking new ideas and are interested in trying new things. They are exposed to a high degree of mass media and have a broader cosmopolitan-type interpersonal relationship with peer networks that usually go beyond their local system. They may not be respected by the other members of the social system, but they play an important role in diffusing a new idea, importing it outside of the social system's boundaries
- Early adopters (*Respectable*): These are people who are also eager to try something new, but do not want to try it first. They are mostly opinion leaders and are generally more respectable than innovators, in a way that they fit more in the local settings of the social system. Potential adopters look up and consult early adopters before using a new idea. Change agents do work closely with early adopters, because they know they are seen as role models by other adopters and will help them decreasing uncertainty about a new idea by adopting it.
- Early majority (*Deliberate*): The early majority group is made of people who do not always want to try new ideas first. They are rarely leaders, but they adopt new ideas before the average person and do not like taking risks:

they will prefer waiting to see if an idea is working before trying it. Their rate of adoption speed lies somewhere between the early and late adopters, make them very important actors in the diffusion process.

- Late majority (*Skeptical*): These are people who are skeptical of change. They will not adopt a new idea, until there is a verifiable proof by the majority that it works. Sometimes their innovation adoption may be a result of an increasing network pressure. They relatively have scarce resources, which requires removing all forms of uncertainty before they are ready to adopt the new idea.
- Laggards (*Traditional*): As by the name, these people lag behind and are usually the last to adopt a new idea. Their point of reference is the past. It is difficult for them to adopt new ideas, because they always refer to what has been done in the previous generations. They therefore often connect with people with traditional beliefs and question the effectiveness of new ideas.

3.2.3.3. Characteristics of adopter categories

Rogers (1983) made generalizations on the difference of characteristics between earlier adopters and late adopters, with regards to socio-economic status, personality variables and communication behaviour.

Socio-Economic characteristics

Innovativeness goes hand in hand with socio-economic status. Roger identified innovativeness varies together with some variables of socio-economic status

- Age: Earlier adopters do not differ from late adopters in age.
- Education: Earlier adopters are more educated than late adopters.
- Literacy: Earlier adopters are more literate than late adopters.
- Social status: Early adopters have higher social status than late adopters (this is attributed to levels of income, possession of wealth, higher standards of living, etc.).
- Sized unit: Early adopters have larger-sized units than late adopters (e.g.: farms, companies).

The economic variables giving a financial advantage to the innovators and early adopters, are some key factors positioning these two adopter categories ahead of the other ones in terms of innovation adoption. In most cases, it will be easier for wealthier individuals to take risky decisions than the poorer, because their economic situation gives them a capacity to bounce back from loss quicker. On the other hand, adopting a new idea require the ownership of initial assets and resources which the poorer and late adopters' group does not have, making them therefore hesitant to take risks. However, this is not an every-time generalization. For instance, agricultural innovators will tend to be wealthier, whereas there are also richer farmers who are not innovators (Rogers 1983).

Communication behaviour

- Connectedness: Earlier adopters are more interconnected in the social system than late adopters. Connectedness is ‘’the degree to which a unit is linked to other units’’ (Rogers 1983).
- Cosmopoliteness: Earlier adopters are more cosmopolite than late adopters. This means they travel more often and are involved in matters beyond boundaries of their social system (e.g.: attending professional meetings). Cosmopoliteness is ‘’the degree to which an individual is oriented outside the social system’’ (Rogers 1983).
- Contacts: Earlier adopters have contacts with change agents than late adopters.
- Media communication channels: Earlier adopters are more exposed to media communication channels than late adopters.
- Interpersonal communication channels: Earlier adopters are more exposed to interpersonal communication channels than late adopters.
- Information seeking: Earlier adopters seek information about innovations more actively than late adopters.
- Knowledge: Earlier adopters have better knowledge of innovations than late adopters.

3.2.4. Social System

A social system is defined as ‘’a set of interrelated units that are engaged in joint problem solving to accomplish a common goal’’ (Rogers 1983). The social system is made of individuals, organisations, informal groups and/or subsystems. As innovation happens in the social system, it is important to study how social structure influences the innovation’s diffusion. For an innovation to successfully adopted, it should be compatible with the structure, norms and leadership within the social system.

3.2.4.1. Social structure and diffusion

Social structure is represented by how different units are arranged within the social system. The relationships and responsibilities of different members of a certain unit of a social system is what constitutes the social structure (Rogers 1983). There is also an informal structure that is found in the interpersonal networks among the members of the social system. This type of structure constitutes what is called *communication structure* and is shaped by communication flows. The social structure therefore can facilitate or impede the diffusion of innovation (ibid)

3.2.4.2. System’s norms

Norms are defined as ‘’established behavior patterns for the members of a social system’’ (Rogers 1983). They are other important factors affecting the rate of innovation’s diffusion, in a way that the attitude and behaviours of individuals or other units of adoption can be barriers to change, creating a certain form of resistance against the diffusion of an innovation. Some are tied to the cultural and religious values, and can operate at different levels (nation, religious community, or local system like a village

4. METHODOLOGY

4.1. Study area

The study was carried out in two districts, Nyabihu and Musanze districts in Western and Northern provinces respectively. This North-Western part of Rwanda has been mostly hit by deadliest floods, dangerous landslides and erosion caused by heavy rainfalls, due to its high elevated landscapes, contrarily to the South-East region which experienced more droughts events (SEI, 2009; Nahayo *et al.,* 2017). Nyabihu District is in the Western province has a surface area of 515.2 km2 (Nisengwe 2016). It has been affected by floods and landslides for so long due to its geographical relief composed of mountains at a 90% level, with more than 55% highly exposed to risks of erosion, landslides and other severe weather hazards (Nahayo *et al.* 2017). The precipitation is around 1400 mm per year and an average temperature of 15 _C (ibid). Musanze district is located in the Northern Province and lays on a surface area of 530.4 km2, of which 60 km2 is in the Volcano National Park (Maniriho & Bizoza 2018). The altitude varies between 1850 m to 4507 m above sea level (Uzamukunda 2015) and includes a chain of 5 volcanoes: Kalisimbi (4,507 km), Muhabura (4127 m), Bisoke (3711 m), Sabyinyo (3574 m) and Gahinga (3474 m) (Maniriho & Bizoza 2018). Due to these higher altitudes, the district a tropical climate characterized by a mean temperature of 20ºC and abundant precipitation throughout the year, with the average annual rainfall varying between 1,400 mm and 1,800 mm (ibid).

4.2. Epistemology and research design

This study was qualitative as it sought to explore and understand the meaning individuals or groups ascribe to a social or human problem (Creswell 2014) which is vulnerability and adaptation to climate hazards in our case. The qualitative approach used in this study is the ‘’constructivism’’ view, which is based on the fact that individuals have different subjective meanings of their experiences, emphasizing on gathering as much as possible participants' views of the situation being studied (Creswell 2014). I was inspired by a phenomenological approach to understand farmers' perceptions on farming vulnerability and the role of meteorological forecasting and early warning systems in reducing the impacts caused by rainfall hazards, looking back on their experiences on the past events that happened to their farming activities at particular places and different times. Phenomenology is a study of observable occurrence, or in other terms a study of how an individual or a group of people perceive, understand, experience, make sense of, respond to, emotionally feel about and engage with, particular objects or circumstances (Inglis & Thorpe 2012). In phenomenological studies, researchers describe the lived experiences of individuals about a phenomenon as described by people involved (Creswell 2014). Using phenomenology in the context of this research, I aimed at understanding how smallholder farmers perceive the seriousness of effects caused by changing rainfall patterns. To better capture their consciousness about those weather shocks, I needed to start with studying closely how their perceptions towards changing rainfall patterns changed over time. In-depth conversations with farmers were conducted through individual interviews, focus group discussions, and important documents to get the full description of their experiences with heavy rainfalls.

When studying the lived experiences by smallholder farmers, I was conscious of my biases and tried my best to avoid mixing my feelings and expectations while interpreting the participants' lived experiences. However, the provision of accurate weather forecast, and emergency warning information is only one aspect of climate change adaptation. It should be matched with numerous other aspects including climate-smart agricultural practices and technologies, good infrastructure, farming on time, and afforestation amongst many: ''Rainfall change is not a hazard in itself. It is only a hazard when it comes into contact with, for example roads, housing and farming practices, or deforested hillsides, causing flooding or other damage (Nightingale 2016)''. To understand better the processes involved in how the weather forecast information is accessed and used this phenomenological approach helped me to understand farmers' perceptions on the prioritization of climate information accessibility vis-à-vis the other climate-smart technologies and practices, as part of climate change resilience process. This is where phenomenology comes in as centrally concerned with individuals' actions and activities (Inglis & Thorpe 2012): One way of phenomenologically approach my research problem, was to examine the adopted rural farming activities (planting on time, community work, etc.), as result of taken decisions after receiving weather forecast information. On this, the objective was to assess how farmers are satisfied by their capacity in managing vulnerable areas on their farms (like steep slopes on hills). With this phenomenological approach, both emic and etic perspectives were considered. Emic in understanding how farmers perceive the phenomena that happen to them. Etic in understanding how key stakeholders interpret the dynamics of climate change impacts to smallholder farmers. In the data analysis process, phenomenology principles also helped me in interpreting the key statements made by farmers, which had evolved through the data collection methods.

4.3. Qualitative data collection

A qualitative research dictates us to be on the field, make observations, and spend as much time as possible with farmers. Data were collected between January and March 2019 and were gathered from primary and secondary sources. Primary data include the data that were obtained from individual interviews and focus group discussions with farmers and organisations. Secondary data were obtained from images, reports, articles and other resourceful documents from other studies. For primary data, I travelled to the field and had interesting in-depth interviews with 21 farmers (8 of them being women) in total and 6 interviews with organizations. A semi-structured questionnaire was used to guide both the individual interviews and focus group discussions, with farmers and key institutions

4.3.1. Sampling respondents

In Nyabihu district alone, I interviewed 6 farmers from Mukamira sector and were all beneficiaries of the Rwanda Climate Services for Agriculture project (implemented by CIAT). Rwanda Climate Services for Agriculture project through its partners DERN helped me to identify these 6 respondents. I interviewed the farmers on the day they had a two-day meeting at Mukamira sector office, where they were discussing about the preparations of the new agricultural season. The sector's agricultural officer who was leading the meeting, knew the purpose of my visit and introduced me to all farmers. I interviewed all the six farmers on the first day of the meeting. In Musanze district, I reached out to the Rwanda Irish Potato farmers' federation (FECOPORWA), who helped me to sample 14 potato farmers from Kinigi sector, and 1 from Musanze sector. Seven farmers were interviewed on each day. All interviewed farmers in Musanze and Nyabihu were selected from the farmers in those two districts but taking into consideration the gender factor. A third of all interviewed farmers were women.

I also facilitated 4 focus group discussions as planned (two in each district and one every day). In Nyabihu, the first FGD was conducted on the first day of their meeting and the second FGD on the second day of the meeting. In Musanze the

FGD included not only the farmers I had individual interviews with, but also other farmers from the same neighbourhood / sector who were selected randomly.

4.3.2. Individual interviews with farmers

The questionnaire destined to farmers was made of questions aimed at studying smallholder farmers' perceptions on climate change, vulnerability of their farms, and the role of weather forecast information in adapting to climate change. Focus group discussions covered the same questions as those from individual interviews but were conducted with an objective of studying how farmers understand effects and coping mechanisms of changing rainfall patterns as a group. The questionnaire targeting institutions was aimed at understanding the role of key institutions in reducing the vulnerability of small-scale farms against heavy rainfall hazards. These institutions included those dealing with meteorological information, agricultural extensions, water management, post-harvest losses.

Table 1: Details of interviewees from Nyabihu District

NYABIHU DISTRICT									
Identification	**Age**	**Sex**	**Education**	**District**	**Sector**	**Family size**	**Crops**	**Farm size**	**Interview date**
Participant 1	26-40	Male	Primary school	Nyabihu	Mukamira	6 < 10	Potato, maize, potato	0.5 ha ≤ 1 ha	2/14/2019
Participant 2	40-55	Male	Secondary school	Nyabihu	Mukamira	6 < 10	Potato, beans, maize	Less than 0.5. ha	2/14/2019
Participant 3	40-55	Male	Primary school	Nyabihu	Mukamira	6 < 10	Potato, beans, maize, and vegetables	Less than 0.5. ha	2/14/2019
Participant 4	56-70	Male	Primary school	Nyabihu	Mukamira	6 < 10	Potato, maize, beans, sorghum, vegetables	0.5 ha ≤ 1 ha	2/14/2019
Participant 5	26-40	Male	Primary school	Nyabihu	Mukamira	6 < 10	Potato, maize, beans, sorghum, vegetables	1 ha ≤ 2 ha	2/14/2019
Participant 6	26-40	Female	Primary school	Nyabihu	Mukamira	6 < 10	Potato, beans, vegetables	1 ha ≤ 2 ha	2/14/2019

Table 2: Details of interviewees from Musanze District

MUSANZE DISTRICT									
Identification	**Age**	**Sex**	**Education**	**District**	**Sector**	**Family size**	**Crops**	**Farm size**	**Interview date**
Participant 7	40-55	Male	Primary school	Musanze	Kinigi	6 < 10	Potato, beans, maize, pyrethrum	0.5 ha ≤ 1 ha	2/19/2019
Participant 8	40-55	Male	3 years of secondary school	Musanze	Kinigi	0 < 5	Potato, Maize, Pyrethrum, (onions and carrots sometimes)	1 ha ≤ 2 ha	2/19/2019
Participant 9	26-40	Female	Primary school	Musanze	Kinigi	6 < 10	Potato	0.5 ha ≤ 1 ha	2/19/2019
Participant 10	18-25	Male	Secondary school	Musanze	Kinigi	0 < 5	Potato, Pyrethrum, Maize,	Less than 0.5. ha	2/19/2019
Participant 11	26-40	Female	Secondary school	Musanze	Kinigi	0 < 5	Potato, Onions, Pyrethrum	0.5 ha ≤ 1 ha	2/19/2019
Participant 12	26-40	Male	3 years secondary school	Musanze	Kinigi	0 < 5	Potato, Maize, Pyrethrum	1 ha ≤ 2 ha	2/19/2019
Participant 13	18-25	Male	University	Musanze	Kinigi	0 < 5	Cabbages, carrots, potato	Less than 0.5. ha	2/19/2019
Participant 14	56-70		4 years secondary school	Musanze	Kinigi	0 < 5	Potato, Maize, Pyrethrum	1 ha ≤ 2 ha	2/19/2019

Participant 15	26-40	Female	2 years of secondary schol	Musanze	Kinigi	0 < 5	Potato, maize, beans, (amaranth, cabbages, carrots)	Less than 0.5. ha	2/20/2019
Participant 16	26-40	Female	Primary school	Musanze	Musanz e	0 < 5	Potato, maize, beans	Less than 0.5. ha	2/20/2019
Participant 17	26-40	Female	Primary school	Musanze	Kinigi	6 < 10	Potato, Maize, Pyrethrum	Less than 0.5. ha	2/20/2019
Participant 18	26-40	Female	5 years primary school	Musanze	Kinigi	6 < 10	Potato, Maize, Beans, Pyrethrum	0.5 ha ≤ 1 ha	2/20/2019
Participant 19	40-55	Male	Primary school	Musanze	Kinigi	6 < 10	Potato, Pyrethrum, Maize, Beans, Onions	0.5 ha ≤ 1 ha	2/20/2019
Participant 20	40-55	Female	Primary school	Musanze	Kinigi	6 < 10	Potato, Maize, Pyrethrum	0.5 ha ≤ 1 ha	2/20/2019
Participant 21	26-40	Male	3 years secondary school	Musanze	Kinigi	0 < 5	Potato, Pyrethrum	1 ha ≤ 2 ha	2/20/2019

4.3.3. Interviewed organisations

I conducted interviews with different governmental and non-governmental organisations, with the aim of distinguishing their different interventions and technologies that are put in place to create more resilient landscapes in rural settlements of the North-West Rwanda and a better use of climate information. The interviews were semi-structured and can be grouped in these categories:

1. The overall organization's mandate.
2. The organization's interventions in climate change adaptation and the provision of climate information services to farmers.
3. Smallholder farming vulnerability capabilities in coping with the impacts and improving preparedness to future hazards.
4. Smallholder farmers' satisfaction of weather forecast information services.
5. The organization's role in improving quality either in the design, provision and/or delivery of the weather forecast information.

Table 3: List of Interviewed organisations

Governmental Institutions / projects
RMA - Rwanda Meteorological Agency
MINAGRI - Ministry of Agriculture and Animal Resources
RWFA - Rwanda water and Forestry Authority
MINEMA - Ministry of Emergency Management
PASP - Post-Harvest and Agri-Business Support Project
Non-Governmental Institutions
CIAT - International Center for Tropical Agriculture / *Rwanda Climate Services for Agriculture project*

4.4. Quantitative data

I received from Rwanda Meteorological Agency, the observed daily rainfall data for Rwankeri_Nyabihu and Ruhengeri Aero_Musanze. I was told that these data were aggregated by merging stations data merged with satellite estimates, between 1981 and 2017. To investigate possible trends for the annual precipitation and rainfall intensity for both stations, I applied a simple regression analysis using linear regression model. For both stations, the annual precipitation and rainfall intensity, the rainfall amount in millimeters (mm) was considered as a depedent variable, and the year as an independent variable.

4.5. Meteo Rwanda Maproom

Maproom is part of the resources/ support functions of the Climate Data Library that is offered by the International Research Institute for Climate and Society. ‘’It is a collection of maps and other figures that monitor climate and societal conditions at present and in the recent past. The maps and figures can be manipulated and are linked to the original data. Even if you are primarily interested in data rather than figures, this is a good place to see which datasets are particularly useful for monitoring current conditions’’ (IRI 2020). Meteo Rwanda Maproom provides data in four different categories: Climate, Climate and Agriculture, Malaria Historical analysis and Climate Summary for Local Governments (Meteo Rwanda 2020).

4.6. Data Analysis

Data was analysed using two approaches:

Qualitative Analysis: Data analysis was done per research sub-themes and per respondents’ category (farmers and institutions). It included an attempt of validating the different respondents’ experiences on farming vulnerability, and of the adoption of weather forecast information in minimizing the disaster risks caused by changing rainfall patterns. This process was done after the fieldwork and involved listing all the key variables gathered from the primary data collection process.

Categorization analysis: The categorization analysis was applied to gender, age and education. As an example, during the data analysis process, attention was put on female respondents’ interventions which emerged from the individual interviews and focus group discussions, in an attempt of phenomenologically study the gender-based perceptions, experiences and needs linked with the purpose of the study.

4.7. Ethical considerations

It is important to provide the respondents with instructions on the purpose of the study before tapping into the interview and/or focus group discussion, while also giving them the right to quit the interview at any time per (Creswell 2014). Before recording each interview, I requested every farmer his/her consent, reiterating that the purpose of it, is linked to the fact that I did not have a rapporteur, therefore recordings would allow me to listen more carefully the discussions. All farmers gave consent in both individual interviews and group discussions. To ensure a smooth running of logistics and commitment from respondents, I gave a small allowance at the completion of individual interviews and/or focus group discussions. Also, these individual interviews and focus group discussions were recorded with the consent of respondents. I also sought for approval from all the organizations interviewed, by writing a request letter for the interview or data. I also informed the local authorities at the district and sector level, before starting the fieldwork's individual interviews and focus group discussions.

5. RESULTS

5.1. Perceptions on the farming vulnerability and adaptation to changing rainfall patterns

This section presents an analysis of social aspects of smallholder farming vulnerability to changing rainfall patterns and flooding hazards in the volcanic region. This means understanding farmers' perceptions and feelings on how their farming was impacted by irregular and unpredictable rainfalls which often result in floods. These perceptions were captured through focus group discussions, in addition to individual interviews with farmers and key institutions.

The vulnerability assessment of heavy rainfalls impact on small-scale farming in the volcanic region, revealed farmers' reactions on the changing rainfall patterns (which disturbs their prediction on when to plant and when to harvest) and other topographical, geological and hydrological factors. Associated with climate variability all these elements contribute to the extreme vulnerability of smallholder farming.

My study area was within the volcanoes' region, more precisely in the surroundings of the Volcanoes National Park. In their responses, farmers indicated their farming is continuously threatened by increasing and unpredictable rainfalls, occurring in both the long rainy season (agricultural season B - February to May) and the short rainy season (season A – October to December). These heavy rainfalls trigger extreme water flows from volcanoes, which overruns with a great intensity, eroding the soil, widening up the water channels and causing rivers to overflow in farmers' fields.

5.1.1. Types of rainfall-related hazards faced

All interviewed farmers reported that their farming has been affected by changes of precipitations in one way or another. These farmers are all involved in potato farming, and some of them combine it with pyrethrum and vegetable farming. They listed soil erosion, flash floods, farm inundations and hailstones as the most challenges associated with an increase of rainfall amount and intensity. Contrarily to what I had initially thought, only one farmer indicated that his farming was affected by landslides hazards. I later figured out that that part of the North-Western Rwanda region is much more vulnerable to floods than landslides.

5.1.2. Harmful effects of heavy rainfalls on crop farming

In terms of losses linked with heavy rainfalls, the destruction and washing away of plants due to soil erosion emerged as the main losses. The chemical fertilizer run-off is another loss identified by farmers due to an increase in rainfall intensity and the looseness of the soil structure, which allows the water to carry on its way the soil nutrients. Similarly, those who are engaged in vegetable farming also expressed the loss is in cabbage and carrots' seeds, whenever an intense rainfall occurs just after the planting of seeds. Heavy rainfalls are also perceived as threats that foster the evolution and spread of crop diseases like the famous potato bacteria disease ''Ralstonia solanacearum'' (called ''junjama'' in kinyarwanda). As per farmers' descriptions, this disease results into a stunted growth of potatoes which got stuck at a certain stage.

5.1.3. Triggers of smallholder farming vulnerability to heavy rainfalls

Climate variability (through seasonal changes), hydrological and topographical factors were perceived as the main factors increasing farming vulnerability to heavy rainfalls and floods.

First and foremost, farmers attribute the vulnerability of their farming, to their increasing incapacity to predict seasons (like how they used to do it before) and believe it is the main triggering factor aggravating the other risks. Almost every respondent stated the changes in seasons' alternation, when trying to recall vulnerability risks associated with changes in the rainfall patterns.

> *''Before, the short-wet season (Umuhindo) was between September – December, but nowadays it extends up to the end of January or even February, having started in October'' - (Male farmer, Nyabihu District).*

Secondly, farmers perceive hydrology as another factor playing a role in making the region's small-scale farming more vulnerable. In my study area, farmers said that three rivers (Muhe, Rwebeya and Susa) and Kampanga stream emanating from the volcanoes, are the main sources of flood risks, as they often overflow due to poor water drainage system. Muhe River and Kampanga stream feed Rwebeya River (Water for Growth Rwanda, 2017). The lack of appropriate drainage system has resulted into formation of Rwebeya, Muhe and Susa gullies, named after the rivers cited above (ENTREM & RTI International 2019). As per my observations, past landscape management activities included creating drainage channels, but these have been constantly damaged. Consequently, farmers described that these damages found all along the drainage channels, allow the water with a great intensity to easily erode the soil surrounding the channels, widening little by little the gullies which continuously extend, resulting in the destruction of nearby farming fields and crop losses.

Thirdly, we have topography as the other key determinant of smallholder farming's vulnerability. As explained by a representative of the Rwandan Water and Forestry Authority (RWFA), the erosion-prone landscapes are other factors behind flash flood occurrence, besides heavy rainfalls.

> *''A heavy rainfall can result into a flash flood or not, depending on the topographical conditions of the area. Most of the times, floods will occur when rainfall meets unprotected catchments, with insufficient conveyance capacity of channelling water. In the North-Western region, the flooding vulnerability is always associated with high altitude topography, inadequate farming and drainage channels which increases runoff. Inundations in farming fields usually happen when the surface runoff gets to a small bridge and overflows'' - (RWFA representative, Kigali).*

The landscape of this volcanic region, being characterized by steep slopes which often lack adequate soil erosion measures, makes farming highly vulnerable to soil erosion (Pavageau *et al.* 2013). Therefore, the flooding risk situation seems to be even more unfavorable for those who do farming in wetlands, as they face more flooding coupled with mudflow events due to these topographical factors. I was interested to hear the different interpretations of farmers on the impacts of heavy rainfall depending on the location of the farming land. Both those who farm on steep slopes and those who farm in marshlands expressed the vulnerability risks against heavy rainfalls and their impacts, but the effects seemed to be worse for those farming in marshlands, as they expressed a more vulnerability caused by mudflow events.

> *''The soil erosion from the hillside affect our farming in the valley. After an intense rainfall, the soil erosion carries away heavy muds from the hills towards the inside and outside of my farm boundaries in the valley, which often result in partitioning our farming land'' - (Male farmer, Musanze District).*

The topographical and hydrological factors are intertwined. The complexity of this volcano area's topography characterized by diverse microclimates (Mikova *et* *al.* 2015), makes it difficult to predict these flooding disasters. As explained by farmers, it is always normal to have rainfalls deep in the volcanoes' mountains, and not in the nearby villages (or just a slight rain), and this increases the flooding consequences, as floods can occur when farmers do not expect them.

> *''Sometimes we are surprised to see Muhe River overflowing on a sunny day, then we know that it has been raining in the volcanoes'' - (Male farmer, Musanze District).*

5.2. Perceptions on the causes and impacts of climate change and variability on farming

This section gives an overview of how farmers in the volcanic regions of Rwanda, generally understand the causes and impacts of climate change and variability on their farming and specifically how they interpret the rainfall changes. It responds adequately to the research question 1.

5.2.1. Perceptions on the causes

Farmers' responses on how they perceive the causes of heavy precipitations and climate variability in general, can be grouped into 2 categories. The first category is represented by around 60% of respondents who proved to be knowledgeable of the danger of activities that harm the environment and connect it to the occurrence of recent natural hazards. In this category, farmers indicated deforestation, as the main threat, showing to what extent they attach the importance of forests in soil erosion mitigation and climate change adaptation in general. Some went on to mention also global warming and greenhouse emissions that come from burning fossil fuels by cars, trucks and industries, as the other key factors.

The second category is approximately 40% of respondents who are totally unaware of the causes of climate change and variability. Most of these farmers, relate the occurrence of heavy rainfalls hazards and climate variability in general, with religious beliefs. Many respondents associated the occurrence of weather and climate-related natural hazards, with apocalyptic beliefs, seeing the increasing severity of heavy rainfalls hazards, as the ''end of the world'' and/or ''God's will''.

> *''I don't know the causes of climate variability. If I don't know where the rain comes from, how can I know the cause? I see it coming from the skies, I ignore what might cause it to be more intense. Since the creation of the world, God preserves the rights to release the rain, so as a believer, I can*

confirm that the end of the world is near'' - (Female farmer, Musanze District).

Other respondents see the changes in weather, as a sign of divine power, anger and punishment.

> *''This is a sign of God's punishment: As a believer who reads the Bible, if I look at the current human sinful activities in the world, and more closely on how our society is losing its cultural values, there is no other explanation I can have, other than seeing this as a manifestation of God's anger to us'' - (Female farmer, Musanze District)*

On this matter, it is also important to note that the analysis of the gender dimension of climate variability perception, revealed that women tend to regard and interpret natural hazards like floods, as dictated by God's will, much more than men do. In all the two scenarios cited above, seven of the eight women interviewed, responded in the same way, explaining the current climate variability patterns as controlled by God (the creator of the world as they said) and has therefore a final say on each and every event happening on earth.

The focus group discussions did not bring out any other views different from the ones illustrated above, other than emphasizing that it is getting more difficult to predict the seasons. Additionally, the farmers in FGD agreed that the landscapes and the world in general is becoming older and older, blaming human activities destroying the environment, as the main causes behind the climate variability.

5.2.2. Comparison with the past 10 - 20 years. *Is the situation regressive or progressive?*

From a historical perspective, it was confusing to hear farmers' different views on whether the situation of heavy precipitation events is either regressive or progressive. Although the question was about the perceptions on the comparison of rainfall patterns between twenty, ten years ago and now, farmers were responding to the question, connecting it more with how their farms' vulnerabilities also evolved during the above-mentioned time periods.

- No change in vulnerability: The majority of farmers responded that the heavy rains experienced 10 years ago and before, were more harmful than the current situation. However, these farmers did mention that it is not really that the heavy precipitations did reduce, but rather that the government invested in the climate-smart agricultural practices (planting of erosion control plants like bamboo and flood tolerant herbs like setaria grass, construction of anti-erosive ditches, hillside terracing) in the last 10 years, highlighting this as the major factor behind the strengthened resilience against erosion and flooding.

- Increasing vulnerability: However, a few other farmers assessed the situation of heavy rainfall hazards of 10-20 years back as better in terms of the harmfulness of effects, than the current rainfall situation, advancing two main reasons. Firstly, they talked about the seasonality changes: these farmers believe the rainfall seasonality has been uncertain and unpredictable in recent years compared to 10-20 years ago. Shorter and longer rainy seasons have been alternating randomly, with no precise forecast prediction of these seasonal rainfall anomalies, and all this is becoming more and more unfavourable to an effective business-oriented potato farming. The years 2014-2016 were highlighted as the period where they experienced the worst, devastating rainfalls which inundated their farms and resulted in considerable decrease in potato yields.

  ‘’I experienced the worst heavy rainfalls in 2015-16. In recent years, the main issue is the lack of rains at the time we expect it, and when it comes it is too intense that it takes away everything on its passageway and lead to enormous damages. Before, my timing of planting was always right to make sure the rain and/or sun doesn’t affect my plants’ growth: I knew that July was too dry, January and February were too sunny as well, and it always started to rain in early March, with a peak in April. I therefore knew which type of crop to plant at a specific time of the season. Nowadays it is quite challenging to grow rain-resistant crops and be surprised by a dry period’’ - (Female farmer, Musanze District)’’

  Secondly, they related this worsening of the situation with the overexploitation of farms and natural resources in general.

  ‘’One reason which make our farms more vulnerable in recent years, is the excessive exploitation of our farms. Before, farmers would alternate crops on their farming land. Nowadays, farmers rarely do crop rotation. Also, before, farms were sometimes put in fallow to allow the soil to recover in terms of organic matter as well as strengthening its resistance to soil erosion. Another factor is on the use of fertilizers: organic manure which we used before is more resistant to soil erosion than the chemical fertilizer which are excessively used in these days’’ - (Male farmer, Nyabihu District).

5.2.3. Analysis and exploration of observed rainfall data at Rwankeri_Nyabihu and Ruhengeri Aero_Musanze

Because of farmers' different views, I was curious to know the correlation between farmers' perceptions and the observed rainfall data. I received from Rwanda Meteorological Agency, the observed daily rainfall data for Rwankeri_Nyabihu and Ruhengeri Aero_Musanze stations representing Mukamira sector and Kinigi sector respectively. These data were aggregated by merging stations data merged with satellite estimate, between 1981-2017. I applied a trend analysis of annual precipitation and rainfall intensity for both stations. I also used graphs from MapRoom (see section 4.5) to analyze the variations of the onset and cessation dates of rainy seasons over the period 1981-2017.

5.2.3.1. Amount of rainfall - Annual precipitation (mm)

The annual precipitation (in mm) was obtained by making a sum of the observed daily data from each station. As seen on figure 2, the lowest and highest amount of rain for Ruhengeri_Aero_Musanze, was 494 mm (in 2017) and 1467 mm (in 1988) respectively. For Rwankeri_Nyabihu, the lowest was 644 mm (in 2017) and the highest 1428 mm (in 2010).

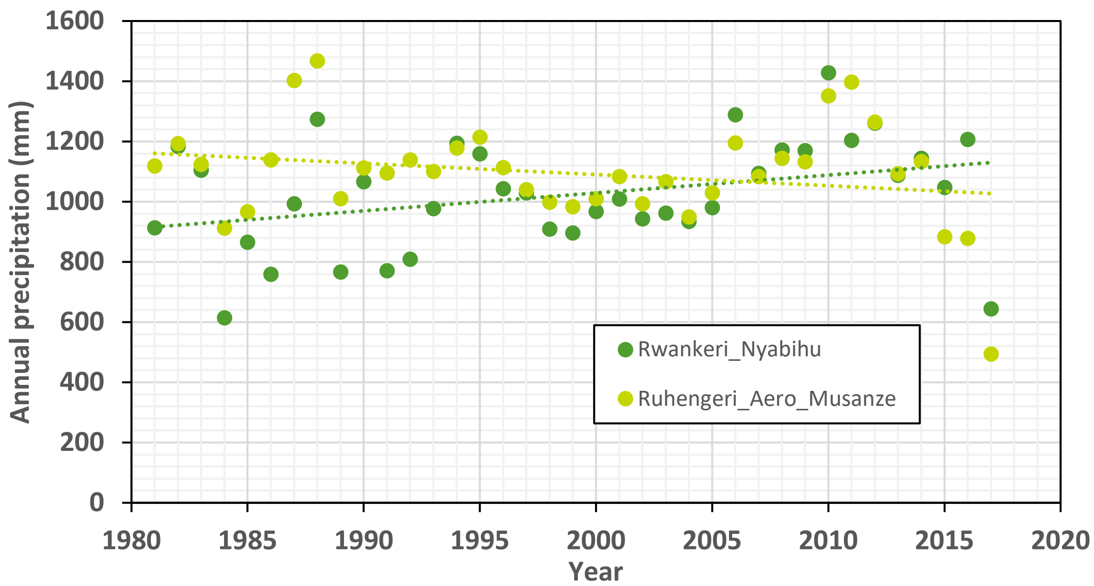

Figure 3: Annual precipitation for Rwankeri_Nyabihu and Ruhengeri Aero_Musanze (1981–2017)

A negative slope was observed for Ruhengeri Aero_Musanze station with a standard error of 168.346 days. P-value was not very small (0.161578) therefore the result is not statistically significant at a 5% level of significance. For Rwankeri_Nyabihu, a positive slope was observed. The standard error was 174.8475 days, the p-value was small (0.033999), which confirmed these values as significant at a 5% level of significance. Basing on these results, it is evident that there has been a significant increase of annual precipitation in Nyabihu and a non-significant decrease in Musanze, over the period 1981 – 2017.

5.2.3.2. Classification per frequency of rainfalls ≥ 15 mm

I grouped the observed daily rainfall data received from RMA, according to the number of days with rainfall > 15 mm for both stations, to see if there has been an increase or decrease in the number of days over the period 1981 – 2017. The years with the highest number of days with rainfall > 15 mm, were 1987 (33 days) and 2010 (28 days) for Ruhengeri_Aero_Musanze and Rwankeri_Nyabihu respectively.

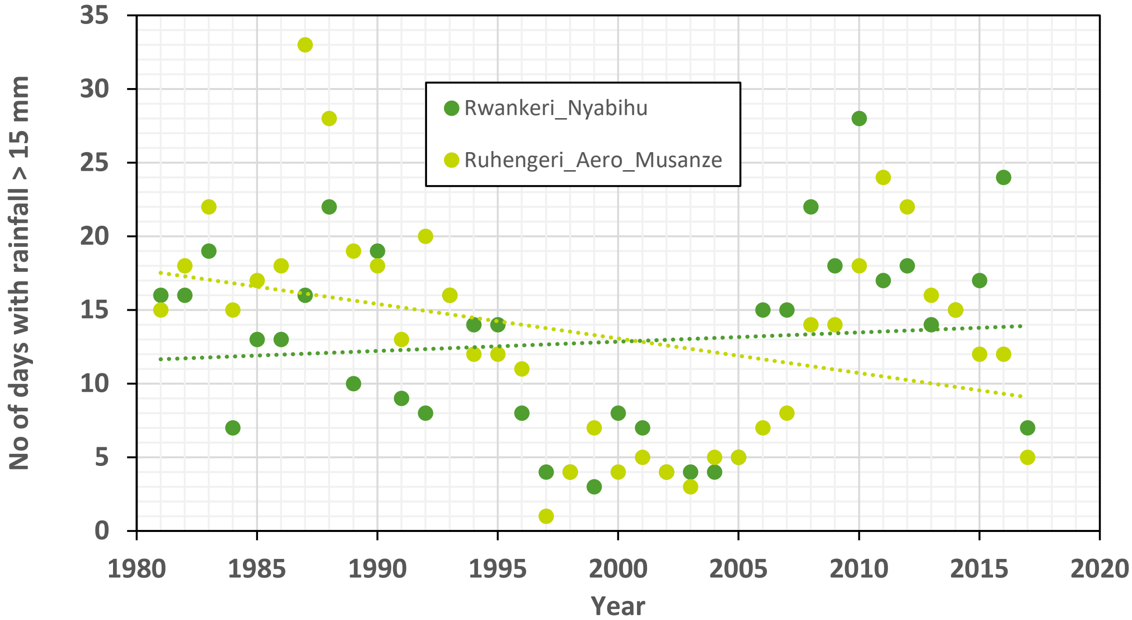

Figure 4: Number of days with rainfall ≥ 15 mm

A negative slope was observed for Ruhengeri_Aero_Musanze with a standard of error of 7.078817 days. P-value was 0.038443, which means it significant to our model, since it is smaller than 0.05. Contrarily, a positive slope was observed for Rwankeri_Nyabihu, with a standard error of 6.484314 and a P-value of 0.533266, meaning the trend was not statistically insignificant at 5% level of significance. From these results, we can deduct that in Musanze, there have been fewer occasions of rainfalls exceeding or equal to 15 mm over the above-mentioned period.

5.2.3.3. Timing of rainfalls

For the timing of rainfalls or seasonality, I was given by Rwanda Meteorological Agency (RMA), the right to use the data from Maproom (see section 4.5) which provides historical data on the onset and cessation dates of the MAM (March-April-May) and SOND (September-October-November-December) seasons. The onset date is defined as a significantly wet event (e.g. 20 mm in 3 days) that is not followed by a dry spell (e.g. 7-day dry spell in the following 21 days) (Meteo Rwanda 2020).

In my case, the onset date was computed as a first window of 5 days that totals 20 mm or more and with at least 3 wet days and that is not followed by a 7-day dry spell within the next 21 days. The early start date was set as the 1st of September for SOND season and the 1st of March for MAM season, and within 60 days. The cessation date was computed as a first date (after 1 Dec for SOND season, or after 1 May for MAM season) in 75 days when the soil water balance falls below 5 mm for a period of 3 days.

SOND (September, October, November, December) 1981-2018:

On the charts below, we can see that while the onset dates for SOND season have been changing over the years 1981-2018, the cessation dates were constant between 1992-2004 and 1995-2003, for Mukamira-Nyabihu and Kinigi-Musanze respectively. From 2005 onwards, the onset and cessation dates have been alternating for both sectors / districts, which matches with the perceptions of farmers who believe climate variability affected the alternation of crop seasons.

<u>KINIGI</u>

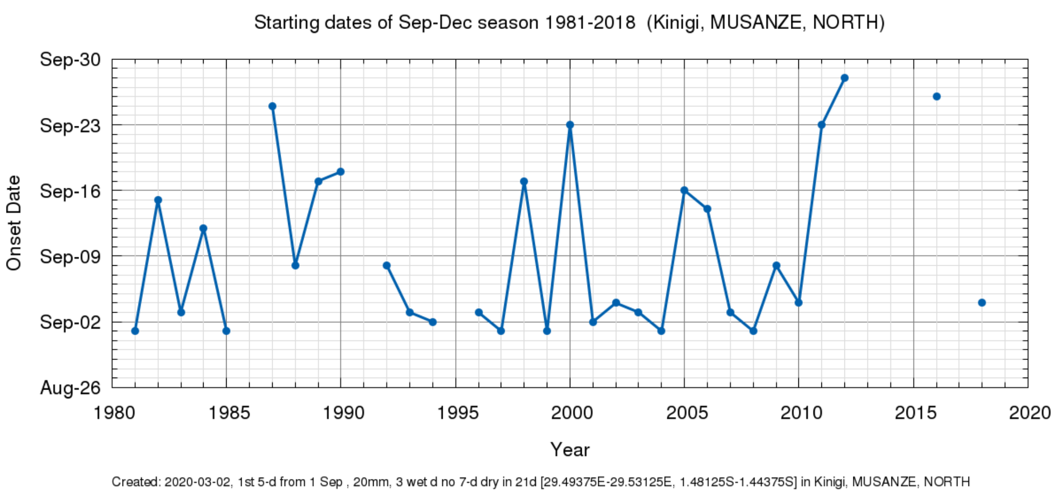

Figure 5: Onset dates of Sep-Dec season 1981-2018 season (Kinigi, Musanze, Northern Province) Source : http://maproom.meteorwanda.gov.rw/

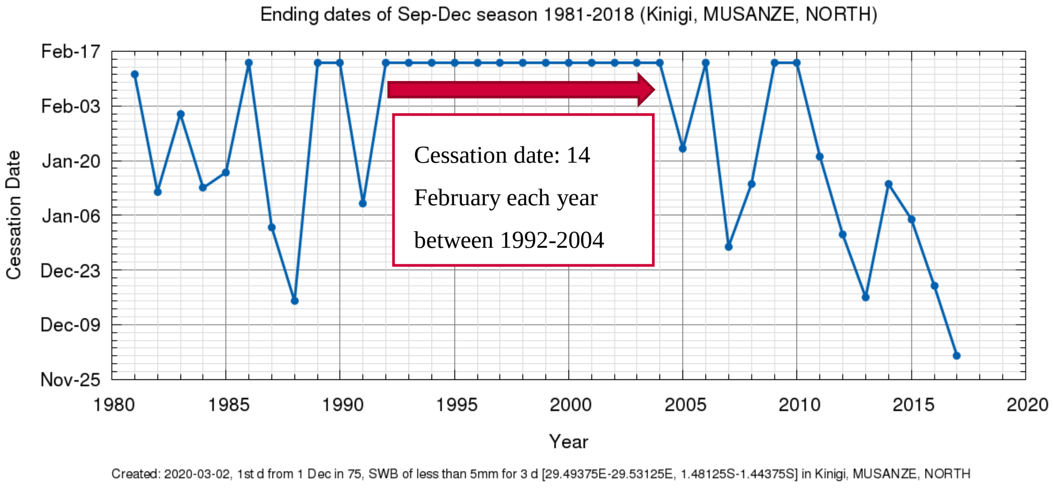

Figure 6: Cessation dates of Sep-Dec season 1981-2018 season (Kinigi, Musanze, Northern Province) Source : adapted from http://maproom.meteorwanda.gov.rw/

MUKAMIRA

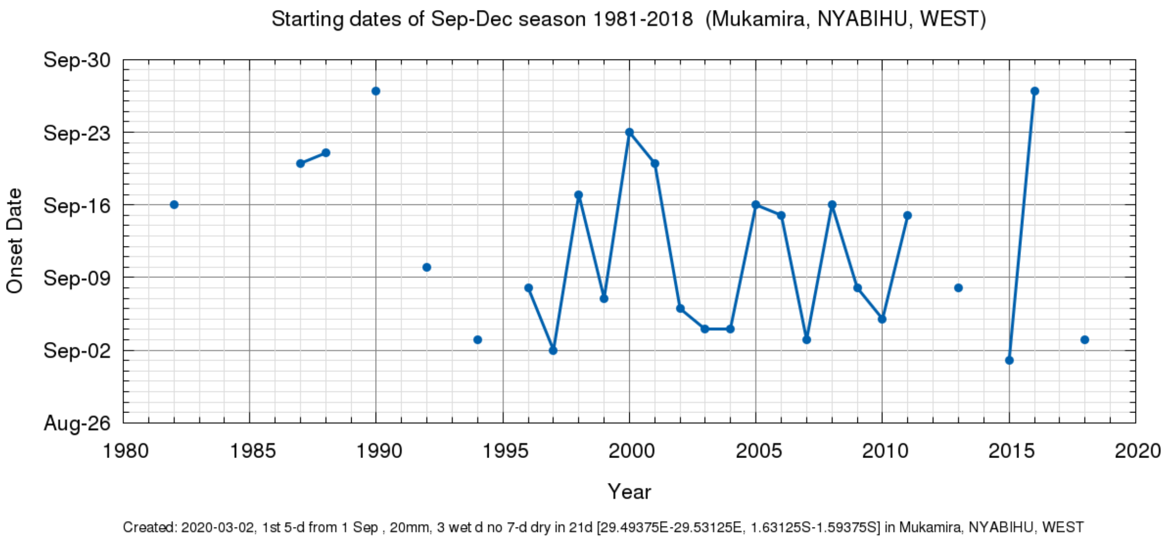

Figure 7: Onset dates of Sep-Dec season 1981-2018 season (Mukamira, Nyabihu, Western Province) Source : http://maproom.meteorwanda.gov.rw/

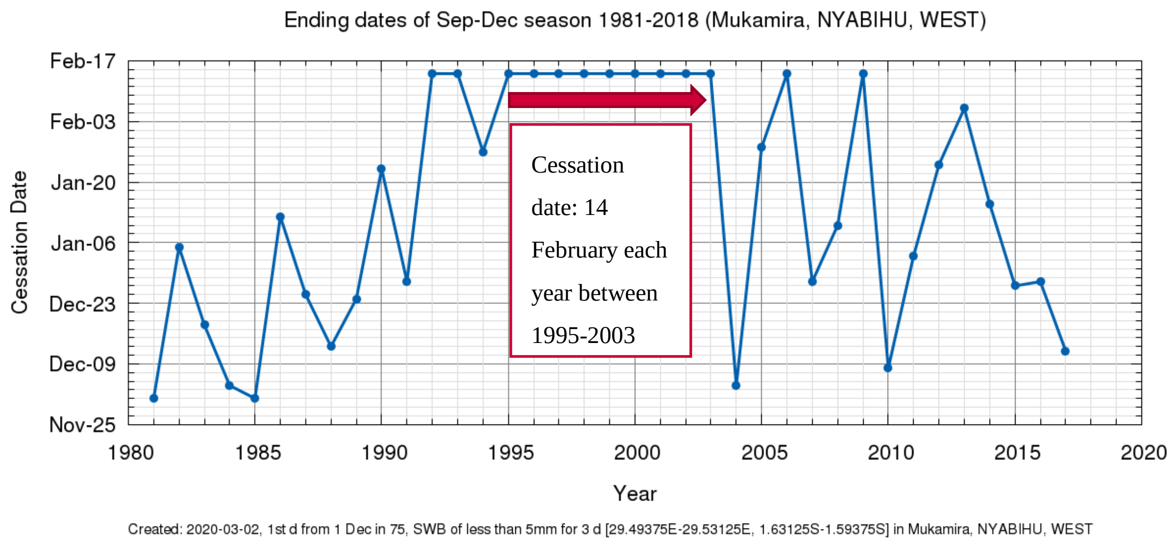

Figure 8: Cessation dates of Sep-Dec season 1981-2018 season (Mukamira, Nyabihu, Western Province) Source : adapted from http://maproom.meteorwanda.gov.rw/

MAM: (March. April, May) 1981-2018:

MAM season is the longest rainy season in Rwanda. The analysis of historical rainy season data shows that generally, there have been changes in the starting dates of MAM season for Kinigi-Musanze between 2013-2018, as well as changes in ending dates of MAM season in Mukamira_Nyabihu over the period 2004-2018.

KINIGI

In Kinigi-Musanze, I realised that the period 1995 – 2013 was somehow characterized by consistent onset dates varying between 1st and the 6th March. Onset dates started changing in a very inconsistent way from 2013 onwards. For instance, the 21st of April 2017 in Musanze was the latest onset date of MAM season over the period 1981-2018 for both sectors.

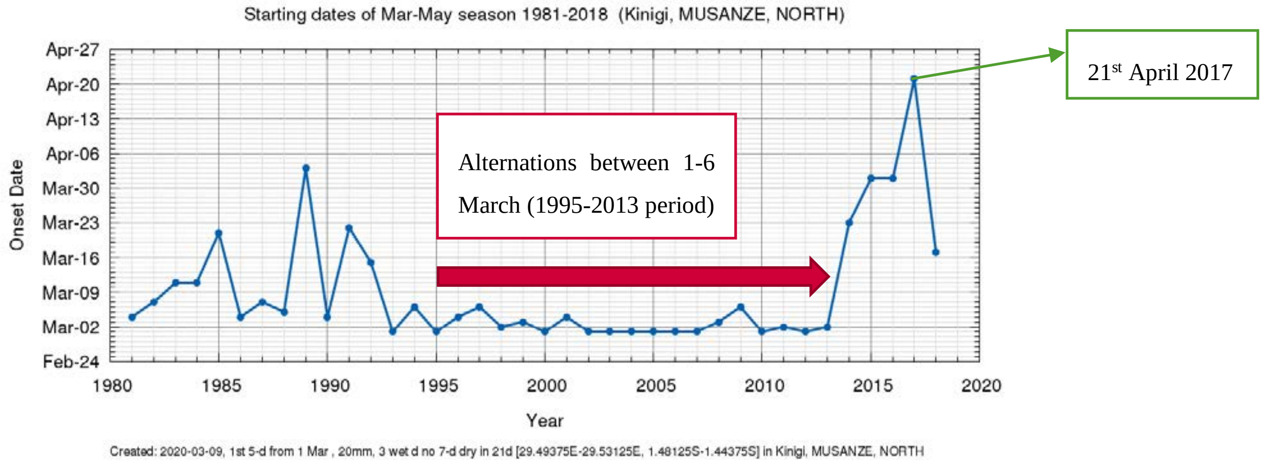

Figure 9: Onset dates of Mar-May season 1981-2018 season (Kinigi, Musanze, Northern Province) Source: adapted from http://maproom.meteorwanda.gov.rw/

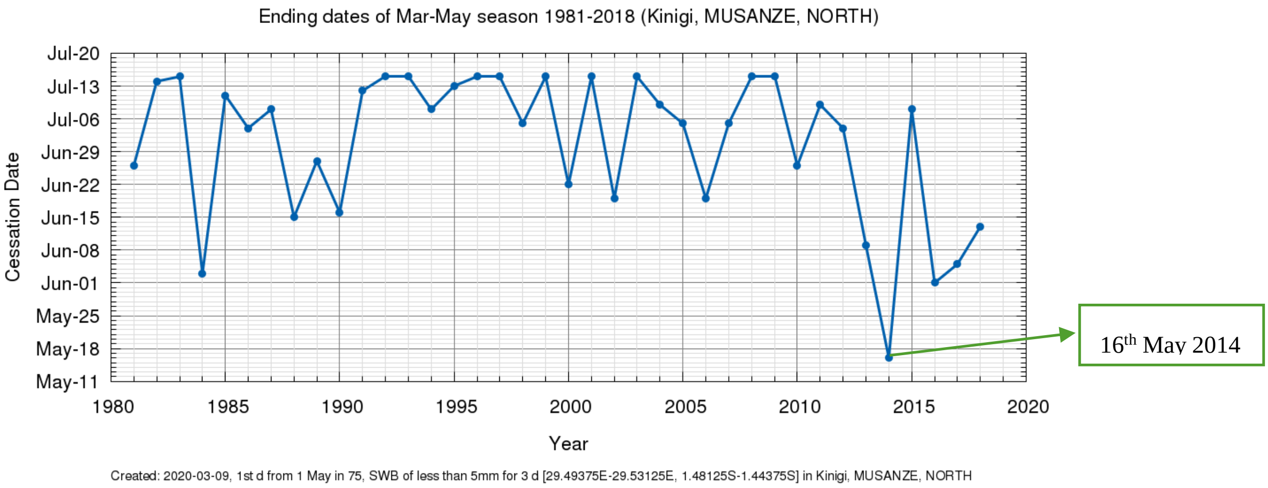

Figure 10: Cessation dates of Mar-May season 1981-2018 season (Kinigi, Musanze, Northern Province) Source : adapted from http://maproom.meteorwanda.gov.rw/

<u>MUKAMIRA</u>

In Mukamira-Nyabihu, for the period 1991-2010, cessation dates have been alternating between 11-30 June (totaling 20 days of difference). On the other hand, for the period 2011-2017, cessation dates varied between 12 May -15 July (that is 64 days of difference).

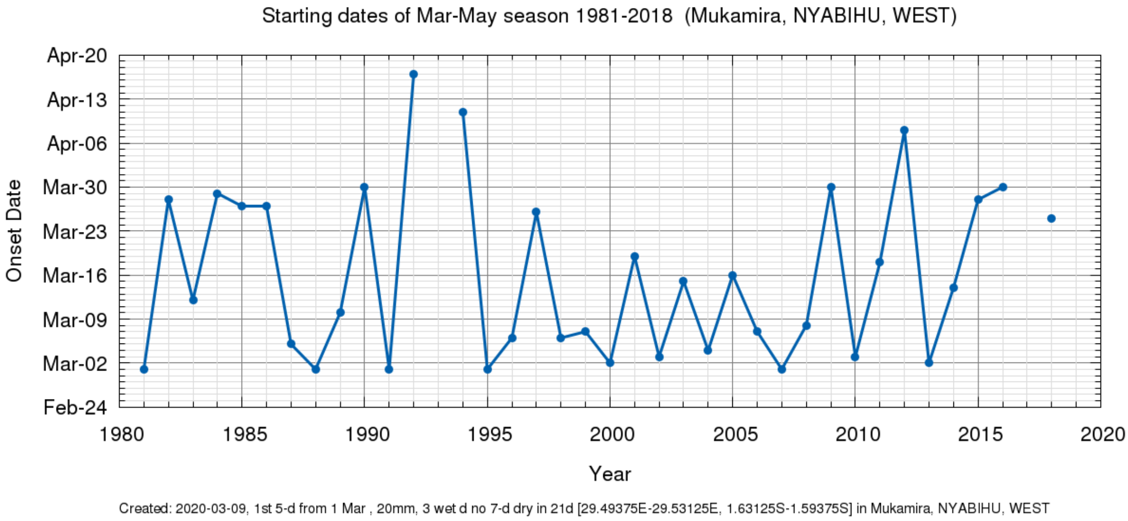

Figure 11: Onset dates of Mar-May season 1981-2018 season (Mukamira, Nyabihu, Western Province) Source : http://maproom.meteorwanda.gov.rw/

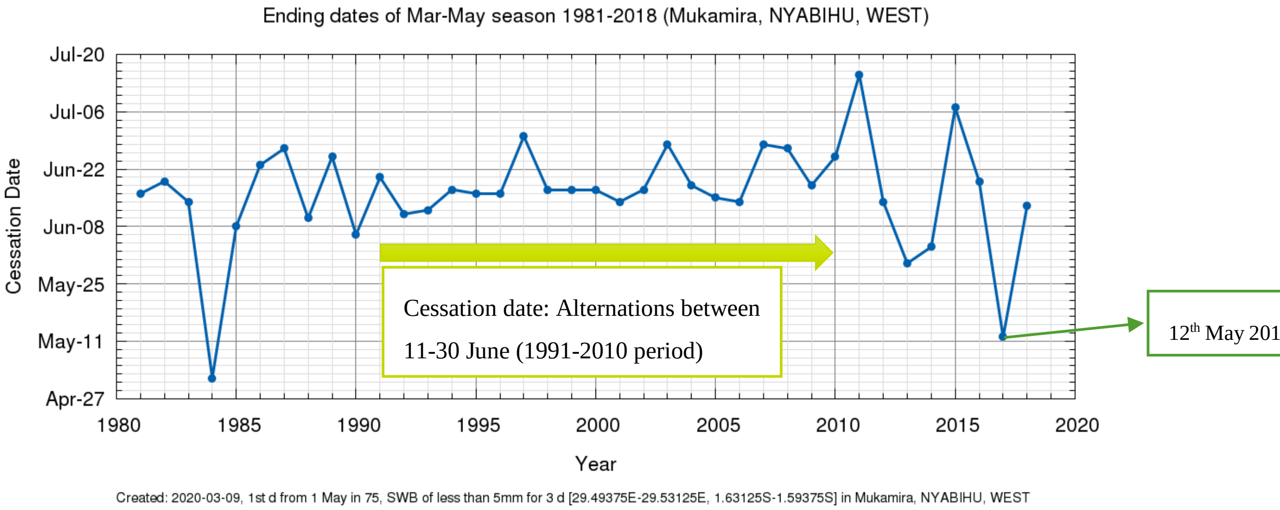

Figure 12: Cessation dates of Mar-May season 1981-2018 season (Mukamira, Nyabihu, Western Province) Source : http://maproom.meteorwanda.gov.rw/

5.3. Adaptive practices and preparedness for future hazards

Farmers listed a number of different practices they do to improve preparedness against heavy rainfalls. From the responses, some practices were more repeated than others. More than 70% of respondents mentioned the construction of anti-erosive ditches, crop rotations, bamboo planting, planting on time, rotating cultivated lands, construction of gabions, afforestation and fallow farming. This confirm how farmers rate them as more important than others. The other practices indicated by nearly 30% included intercropping setaria grass, digging holes on the farm boundaries and agro-insurance.

Hillside terracing

As reported by a representative of the ''Rwanda Water and Forestry Authority'' (RWFA) and highly praised by farmers, the practice of hillside terracing has contributed a lot in sustainable land management by reducing water run-off velocity and controlling soil erosion hazards on steep slopes. In each of those government programs for terracing, local farmers themselves are hired in building the terraces, as part of land conservation technology and knowledge-transfer of the program.

> *''When it is time to do hillside terracing or planting trees, we always hire the local people regardless of their prior knowledge / experience in those activities. The goal is to make sure that by the end of the project, farmers know the benefits of hillside terracing, on top of knowing how to build, manage and protect them''* - (RWFA representative, Kigali)

Construction of anti-erosion ditches

From farmers' responses, the practice of construction of anti-erosion ditches emerged as the most important erosion control technique: it was cited the most by the majority of farmers in both districts. This technique prevents soil erosion by retaining more rainwater in the ditches, reducing its runoff and improving better infiltration. Farmers expressed the need to constantly check the width of ditches, to ensure effective erosion control.

> *''Before, the soil erosion impacts were not that much harmful, but nowadays, due to the frequent heavy precipitations, everyone has to dig anti-erosion ditches on the hillside and especially on their farms' boundaries, to retain water and reduce its pressure'' - (Female farmer, Musanze District)*

Planting on time

A rainfall-based planting time approach is seen by farmers as a technique which could limit the losses all along the potato value chain stages. Farmers in both districts see it as the starting point in limiting the effects of a changing climate on agricultural productivity. Decisions on the right time to plant depend on seasonal forecast which (according to farmers) is also still difficult to accurately predict (see section 5.3.1.1.).

‘’With this weather becoming more and more uncertain, not knowing precisely the right time to plant affect considerably crop growth and agricultural production, resulting in crop yield losses from the growth up to the harvest of potatoes’’ - (Female farmer, Musanze District)

Fallow farming

Fallow farming is another adaptation technique Musanze farmers specifically indicated adopting occasionally when faced with increasing rainfalls. From their experiences, this farming practice is done primarily to avoid crop losses during a season with extreme rainfalls, but also to improve soil fertility and crop yields in the following season.

‘’Some farmers who have enough arable land (like 2 ha and above) prefer not to do farming in the rainy season between February and May, because they know it is a season with lots of disasters. They wait for the following season B starting from August/September. The sun from June, improves soil health by removing the bacteria and viruses in the soil’’ - (Male farmer, Musanze District)

Crop rotation

A few farmers indicated crop rotation as a technique to mitigate the effects of intense rainfalls, through adopting heavy precipitation-tolerant crops. As reported by farmers, the main target is more about minimizing losses and less about improving yields and income. Farmers also praised improvements in soil health as an indirect result of rotating crops.

‘’I personally decided to grow peas and wheat during rainy seasons, as they are more resistant to heavy rainfalls than potatoes. The only threat that seems to disturb peas is hailstones rain.’’ - (Male farmer, Musanze District)

Rotating cultivated lands

This technique was shared by two farmers from Musanze, who occasionally opt out from doing farming in lowlands during the long rainy seasons.

‘’I can choose to farm on the slopes during the heavy rainfall’s seasons, and farm in the wetland / valley during the sunny season’’- (Male farmer, Musanze District)

Off-farm activities

Due to frequent and immense crop losses, two farmers in Musanze indicated that they decided to no longer invest all their energy and capital in farming during the long rainy season.

> *''When I know it is a season of intense precipitations, I combine both farming and small-scale business. (There is no reason to put all eggs in one basket), when I am not sure of my return on investment in agriculture''- (Female farmer, Nyabihu District).*

Of farmers in Musanze, some indicated applying special pesticides like LUDOMIR which are known for being more resistant and having much more positive effects in a time of heavy rainfalls than others.

During FGD, the main objective was to assess adaptive practices done by farmers as a group, to reduce the vulnerability. Farmers emphasized that it has been progressively becoming hard to predict the seasons. Among the adaptive practices done as a community, Nyabihu farmers mentioned hillside terracing and anti-erosion ditches on hilly slopes and digging holes that retain water in wetlands and valleys. They claimed that to do these practices, they rely more often on their indigenous knowledge rather than meteorological information.

> *''We do the soil erosion practices, basing on our general seasonal knowledge, not because we have been communicated the weather forecast and/or early warning information. Sometimes yes, agronomists can intervene and sensitize us on what to do, but generally we also take the first step depending on the expected seasons'' - (Farmers Group discussion, Nyabihu District)*

Construction of gabions

Again, as part of FGD, farmers revealed having cooperated with the government since early 2012, in the construction of gabions (made of volcanic rocks, sustained by metal wires) inside gullies,_to limit the flow and speed of the water from volcanoes and thereby reduce flooding risks. Unfortunately, the gabions have been either partly or completely destroyed, and no more play their flood protection role. During my personal observations, by looking at gullies' widths I realized how intense is the pressure and velocity of water, which farmers claimed to have also carried away buffalos all the way from the volcanoes in the past years.

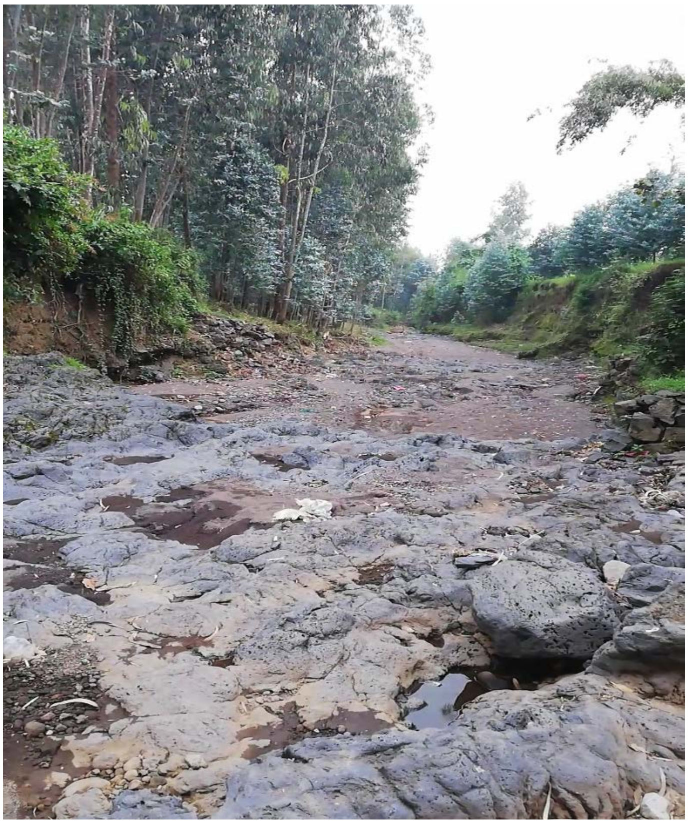

Figure 13: The width of water gullies is increasing due to soil erosion (Photo by Didier Muyiramye, February 2019)

Bamboo planting

Musanze farmers also have been joining efforts to plant bamboo around riverbanks, especially at the intersections of streams.

> *‘’Planting bamboos has proven to be effective soil erosion control techniques by protecting gullies’ banks. Their roots play a critical role in holding the soil, preventing it to be eroded by flooding water’’ - (Male farmer, Musanze district).*

Minimising effects right after a heavy rainfall

A general perception of all interviewed farmers is that there is nothing they can do to limit the impact of heavy rainfalls or be compensated in one way or another for the agricultural losses incurred, right after a devastating rainfall happens. More than 90% of respondents did not have or have never subscribed to any agri-insurance products, by the time we interviewed them.

> *‘’Nothing! You cannot get back what you lost. Only when you have agri-insurance, you can get like 50% of what you lost (but I did not insure my*

> *crops). For the houses, the government always intervenes as quick as they can, and you can be provided a new shelter, but for the crop losses, it is so hard, you must find a solution yourself (laughing)'' - (Female farmer, Musanze District)*

Only two farmers indicated doing activities that manage rainwater during or right after a heavy rainfall

> *''I dig holes inside and at the boundaries of my farm, to retain more water and prevent it from entering my neighbour's farm field or house'' - (Male farmer, Musanze District)*

> *''Right after or even during a heavy rainfall, I sometimes take a hoe, go to my farm, and try to direct the rainwater on the boundaries of my farm, to prevent it from entering my cultivated land'' - (Female farmer, Musanze District).*

Umuganda

Another important community work that is proven to have highly contributed in preventing land degradation is ''Umuganda'', which literally means *"coming together in common purpose to achieve a certain objective."* Citizens over 16 years of age are expected to participate in this collective work for all which takes place every last Saturday of the month. It is most of the times organized at *Umudugud**u*** level, the smallest level of territorial administration. Being an indigenous practice that takes roots from the Rwandan culture, farmers had a lot of confidence in it. Tree planting and hillside terracing are among numerous activities carried out during umuganda that farmers indicated as important contributors to soil erosion control and environmental protection. From their responses, it was clear to feel how much importance they attach to ''Umuganda'' in terms of social coherence, obligation and responsibility, as well as information-sharing, as the last hour is always dedicated to discussions with the local authority. Farmers intervene and share their opinions and ideas on a number of issues including agriculture and environmental degradation.

> *''During umuganda community work, we do work together on the activities that strengthen the resilience of our landscapes against heavy rainfalls. We also support each other through Umuganda. For example, when one of the farmers' fields have been flooded, we go help him or her in digging water channels, because we know if the water passage is blocked at his/her farm, the flooding impact will reach other farmers' fields as well'' - (Male farmer, Musanze District)*

However, as the discussion was going deeper and deeper, I found out that sometimes (during one Umuganda community workday), resolving one landscape vulnerability issue in one Umudugudu, could be a threat and create more risks to another Umudugudu.

> *‘’As we are constantly faced with flooding risks originating from a river in Bisate area, the local authorities planned ‘’Umuganda’’ (on our umudugu level) that we executed in rehabilitating drainage networks and channels from the top of the hill up to the end of our village. We hope that those from a neighbouring umudugudu will do the same’’ - (Male farmer, Musanze District)*

This means that the issue was partly solved and is not sustainable in a long-term perspective, as it exposed more flooding risks to the neighbouring village. To be able to achieve more environmental protection results on ‘’Umuganda’’ agenda, there is a need of having a clear strategy to harmonize the joint planning of these climate-smart practices taking into consideration the vulnerability on a larger geographical scale.

5.4. Access and use of weather forecast and flood warning information in farming decision making

If packaged, disseminated and used well, weather forecast and early warning information can significantly challenge and reduce the effects and impact of natural disasters (UNDP 2016). This section presents results on the accessibility of the weather forecast and early warning information to farmers, looking more closely on their different forms, the sources and dissemination channels set and operated by key institutions. It later investigates farmers’ responses on the utilization of the received information in making informed farming decisions that help them cope better with extreme rainfall events.

5.4.1. Accessibility

5.4.1.1. Weather forecast information

The Rwanda Meteorological Agency (RMA) is the government-owned institution in charge of designing, interpreting and disseminating the weather and climate information services (from short-term to long-term forecasts) to a number of users including farmers.

> *‘’ RMA has the mission of providing accurate, timely weather and climate information and products for the general welfare of*

Rwandans. The weather and climate information produced includes nowcasting (1min-3 hours, 6-24 hours), short-range forecasts (1-3 days), medium-range forecasts (7-10 days bulletin) and extended-range forecasts (monthly outlook or 3 months seasonal forecast). The 3-month forecast is updated every month and is generally the type of forecast that farmers need most. For the long rainy season between March and May, we go on field (together with the Rwanda Agriculture Board staff and agronomists) to disseminate the forecasted information and advising farmers on how to orient their farming decisions, taking into consideration the seasonal forecast. This is always done 15 days before the seasonal forecast information is released'' - (RMA representative, Kigali).

To update farmers on weather changes, RMA disseminates information via numerous tools including mobile phones (SMS and/or USSD), radios, TVs, social media or in meetings. Below we have a look at each dissemination tool and how it is perceived and used by farmers. While the other channels can be used to disseminate both short-term forecast (1 to 7 days) and long-term forecasts (1 to 3 months), the SMS/USSD is only used for a 3-day maximum weather forecast.

Radio

Radio is used to disseminate all types of weather forecasts. According to the RMA staff I interviewed, among many information communication channels, radio emerges as the most efficient tool, playing a prominent role in disseminating weather forecast information.

''Radio is the most efficient communication tool we use to disseminate the weather forecast information. We work predominantly with Radio Rwanda (as the most listened to radio) but also with its subordinate radios also called ''community radios'' and a very few private radio stations. We send them the information early in the morning and they broadcast it at 6 a.m. and in the evening (RMA representative, Kigali)''

More than two thirds of the farmers interviewed (especially the older ones) also highly rated the radio for being reliable, easy to use and to capture the information better than mobile text messaging. Moreover, it is also important to indicate the different views of farmers, on the willingness of listening to the information on the radio. According to approximately half of respondents, listening to weather forecast information comes occasionally, while they are listening to other news and radio programs.

HUGUKA Radio, which focuses mainly its broadcasts emissions on agriculture, is one of the highly rated radio stations by farmers for communicating daily weather forecasts and running talk shows on agricultural matters, including climate information services.

> *‘’Yes, I access the information through Radio Huguka, or Rwanda Television. I don’t have the time to check the info on the phone on a daily basis, but overall I think I know how it works, it is one of the tools I can also use once in a while to check the information’’ - (Male farmer, Nyabihu District)*

A representative of HUGUKA radio mentioned that some farmers have captured well the importance of the weather forecast information to the point that they even call to the radio requesting the information

> *‘’Farmers are getting more and more interested in knowing about weather changes. They have been calling to seek information. Apart from our radio talk shows, we also send SMSes to farmer leaders grouped in 225 associations, representing 17 districts in total. Farmers in Musanze and Nyabihu districts are among those who follow our programs the most’’ - (HUGUKA Radio representative, Kigali)*

Mobile phones (SMS and USSD services)

As per farmers’ responses, mobile phones are the second most popular source of weather forecast information. On the mobile phones, the daily forecast information on a district level, is provided either by Short Message Service (SMS) or by Unstructured Supplementary Service Data (USSD) technology. Both of these services do not don’t require a smartphone or internet. By SMS, a farmer receives automatically a text message with forecasts on weather and climate changes. As a representative of RMA told me, SMSes are sent on daily basis, but not to all farmers.

> *‘’We send SMS every morning. Our goal is to be able to send the information to every farmer in the country with a phone, but this is not feasible for the moment as we currently only have around 7,000 farmers in our database (with some districts having a larger number of farmers than others). Through our regular meetings with farmers, we record their phone numbers and update our database. The target is to have at least 15,000 by March 2019 and around 50,000 by December 2019’’ (RMA representative, Kigali).*

Contrarily to the SMS system, using the USSD system requires dialing *845# on the phone and involves running through a number of steps before getting the desired information of 1 to 7 days only. The complexity of this USSD service is a challenge for farmers with less digital skills. I found a low adoption of digital services especially in old farmers and women due to the inability to run different sessions required to get the information on the phone. Additionally, some farmers are not even aware that the USSD service of checking the weather forecast on the phone is free of charge and can work with any type of mobile phone. They believe it can only work on the smartphone.

> *‘’ I rely mostly on the radio. Only those who have smartphones (like - he mentions the name of another farmer) access the weather forecast, but with normal phones like mine, never!’’ - (Male farmer, Musanze District)*

One of the reasons behind favoring radio over phones, could be linked with the digital divide issues. I found that the adoption of digital services is still disproportionate among farmers, leaving digital illiterate farmers with an option of preferring to listen to the radio. The digital divide is most pronounced between young and old farmers: Although the service of getting daily forecast on the phone using the USSD system is praised by relatively young farmers for being free of charge, easy to use and providing information covering each and every district in the country, the old farmers expressed their inability in either to afford the mobile phones or to access the forecasted information via phones, due to digital illiteracy.

> *‘’Normally to be updated on weather forecast, I listen to the radio or hear the information from neighbours. But when it is holiday time, my children also help me to get the information on the phone. I am not able to check the information on the phone by myself’’ (Male farmer, Nyabihu District).*

> *‘’Yes, sometimes I receive the weather forecast information while listening to the radio. I have never searched for information on the phone: I am not knowledgeable on how it works’’ (Female farmer, Musanze District).*

Another reason that pushes farmers to rely on the radio over mobile phone, is the ease of getting the information. Farmers expressed indirectly how checking regularly the weather forecast on the phone is time consuming for them, which is why they often prefer listening to the radio.

> *‘’Yes, I access the information through Radio Huguka, or Rwanda Television sometimes. I don’t have the time to check the info on the*

phone on a daily basis, but overall I think I know how it works, it is one of the tools I can also use to check the information once in a while (Male farmer, Nyabihu District).

Television

Most of the farmers I interviewed, do not own televisions at their homes, principally due to a lack of financial means to afford one. Only four farmers (all from Musanze District) indicated receiving the weather forecast information on television on a daily basis. Generally, assessing their responses on all the questions, these four farmers seemed to be more knowledgeable about weather forecast than others, due to the fact that all of them regularly check weather change updates also on other communication channels (radio and mobile phones).

‘’My main sources of information for seasonal forecasts are television and radio. On the phone we only access the daily weather forecast which is also limited to a district level. To be updated on how the weather will look like on a national scale, I watch the news on Rwanda Television’’ (Male farmers, Musanze District).

Community meetings

Only a few farmer cooperatives’ leaders indicated that they get seasonal forecast information through meetings and trainings with Rwanda Agriculture Board and other key stakeholders, before the start of a new agricultural season. A representative of the Post-Harvest and Agribusiness Support Project (PASP) explained to me how these meetings are organized.

‘’ Together with RAB and RMA we organize regular meetings on district levels, where we invite agricultural officers on sector levels, cooperative leaders, input suppliers. We communicate the status of weather in the upcoming season. Depending on the 3-month seasonal rainfall prediction, RAB advises farmers on which crop variety to adopt’’ - (PASP representative, Kigali).

The idea behind the organization of those meetings is to disseminate seasonal forecast or early warning information (in an efficient and fast way) from cooperative leaders/representatives to all the farmers. However, I found a gap in the distribution and accessibility of seasonal forecast information. The majority of farmers claimed to never receive the seasonal forecasts. RMA, PASP and MINAGRI all recognize this gap. Unfortunately (according to these organisations), contrarily to the daily forecasts which are transmitted via phones, the seasonal forecasts or early warning information contain too complex information and is therefore difficult to summarize in a single text message, which is why they opt to organize meetings.

> *'' Disseminating the seasonal forecast to all farmers (through regular meetings) would involve outstanding financial resources. At the same time, this 3-month seasonal forecast requires communicating too many details. It is too complex (in a way that it involves long-term planning and decisions), therefore you cannot summarize it in a short message; it would be misleading. We recognize this gap and continue working on it, that is why now, it is only communicated through meetings to be able to explain all details (PASP representative, Kigali)''.*

Farmer-to-farmer information-sharing

Asked if there is any information mechanism that disseminate the seasonal forecast information among themselves, both farmers' categories from Musanze and Nyabihu confirmed that it is almost non-existent.

> *''Only when we meet RAB extension officers, we can be briefed on what to do, based on the weather forecast. In that case, we can inform other farmers. Apart from that, the dissemination of the information between us is not strong'' - (FGD, Nyabihu District).*

> *''On very few occasions, ''Umujyanama w'ubuhinzi'' (agricultural advisor-elected farmer) sometimes communicates to us the 4-months seasonal forecast information (once he is coming a workshop on a new planting season). But this happens rarely'' - (FGD, Musanze District).*

Basing on the past experience, a representative of the Ministry of Agriculture indicated that, even when farmers try to transfer the weather forecasts between themselves, most of the times the content of the message is lost along the information-sharing chain.

> *'' The dissemination of forecast information from a farmer promoter to other farmers is questionable. As the information is shared among farmers, we often realize that the content of the message change, due to a lack of knowledge in interpreting correctly the terminology of forecast information'' (Ministry of Agriculture and Animal Resources Representative, Kigali).*

Social Media / WhatsApp forums

Even though most of the farmers do not access the internet or do not use social media, RMA indicated also sharing the weather information updates on WhatsApp forums. The idea behind being, the receivers of the information to disseminate it to the concerned farmers.

> *''We do have different* What's App *groups categorized into ministerial levels (MINAGRI and MINEMA) and local government levels (southern, western, eastern, northern province), where we share with the* What's App *group members, the weather forecasts every 6 hours (at 6 a.m., 12 p.m., 6 p.m. and 12 a.m.). We make sure the district agronomists and cooperative leaders are included in those forums. We also have a separate* WhatsApp *forum for journalists. Journalists play a very crucial role in distributing the information, as well as getting feedback from farmers (Northern-Western farmers are the ones who give feedback the most).*

Unfortunately, despite the fact that RMA has been disseminating the weather forecast information on different channels (radio, mobile phones, television, community meetings), farmers believe there is still a gap in ensuring equal and timely access to information to everyone. For instance, farmers claim there is an imbalance of accessing seasonal forecast communication on the onset of rainy seasons. Some never receive it; some others receive it occasionally.

> *''My request to the in-charge institutions, is to improve the dissemination of the seasonal forecast to all the farmers. Not only occasionally. Also, the timing is crucial to be able to make the right decisions'' (Male farmer, Nyabihu District).*

During FGD, Nyabihu farmers reaffirmed radio and mobile phones, as their main sources of information. However, the ignorance and illiteracy of farmers in adopting digital ways of delivering forecast information reappeared in the FGD as a crucial factor limiting access and use of forecast information. In the middle of one FGD, a farmer indicated checking the forecasts every day and the others seemed to be surprised and started asking him what he does to access the information. He took a few minutes to show the whole process with all required steps to run before reaching the information.

Figure 14: A farmer explaining other farmers, how to check daily forecasts on the phone (Photo by Didier Muyiramye, February 2019)

In another FGD, a farmer said that through the USSD on the phone, you can access the forecast information, up to cell level (which is not true, as the forecast disseminated target the district level) and no one disagreed with him. I immediately intervened and asked if what he said is true, and they started disagreeing, some affirming the information is forecasted up to a district level, others indicating cell level. This clearly showed that farmers' knowledge capacity of checking the forecast information is still low.

From the FGD, although seasonal forecasts are generally less accurate than daily weather forecast (an assumption that also farmers understand), the majority of interviewed farmers perceive seasonal forecasts to be more valuable than daily weather forecast. However, only a few of interviewed farmers indicated that they get seasonal forecasts. A larger number said that they rarely or never receive seasonal forecasts.

5.4.1.2. Early warning information

As for the general short-term and long-term weather forecast information, only RMA is responsible of designing and packaging the early warning information, and shares it with key institutions like the Ministry of Emergency Management, The Ministry of Agriculture and Animal Resources, the Rwanda Water and Forestry Agency, or directly to the farmers.

MINEMA is only involved in the dissemination of early warning information, through the distribution of the early warning alerts to the end users. As reported by MINEMA, their early warning information is currently disseminated directly to 2032 people who are in their database and are part of the District and Sector disaster management committees. These are assigned to distribute the received information to the rest of the community, including farmers.

> *‘’ Our current database includes a number of local leaders, policy and army officers, social affairs staff, agronomists and veterinarians on both the district and sector levels, 800 law enforcers or ‘’inkeragutabara’’ (reserve force), 199 indigenous knowledge users (taken from 9 districts). We give them the information and make sure they are equipped with communication means to ensure they are able to disseminate the information (MINEMA representative, Kigali)*

I asked MINEMA whether they categorize the information depending on the sectors (e.g.: agriculture, water, housing), type of disaster or regions, or more precisely if they design the information specifically targeting farmers. Apparently, it is not something they currently do:

> *‘’ The early warning alert that we distribute is not specifically designed to agriculture. It is MINAGRI which should make it more relevant to farmers’’ - (MINEMA representative, Kigali).*

Among the channels used by MINEMA to dissemination the early warning alerts, there are official letters distributed to local leaders in cells and villages, when disasters are predicted as highly imminent. These letters are read to citizens during the community working days ‘’Umuganda’’, informing people the required preparedness actions to take against the disasters. MINEMA also sends out emails, SMS and WhatsApp to institutions and focal points on district levels. It also organizes radio and TV Talk shows occasionally.

Unfortunately, with all these systems in place, it is still difficult for the early warning alerts to reach all farmers. Only two farmers I interviewed, reported having received flood forecast information ahead of a certain flooding event. These farmers indicated that even when they receive such information, it is mostly focused more on alerting those living in highly-risk zones on the possibilities of evacuation, and less about farming risks.

By discussing with each institution separately, I understood how the lack of collaboration between the involved institutions is probably, the main gap hindering the efficient dissemination of early warning information to farmers. Institutions themselves feel challenged by this gap and reported currently working on different initiatives to bridge this gap, not only the early warning alerts, but the weather forecast information in general.

> *‘’ We also have initiated the National Climate Outreach Forum (NCOF), which brings together MINEMA, RAB, MINAGRI, RWFA and other key partners to discuss the applicability of the weather and climate forecast in every sector, communicating the quantity of the expected rain. This is done on a district level, although the plan is to take it to the sector level’’ - (RMA Representative, Kigali)’’*

Additionally, the content and terminology of early warning information is also questionable by institutions and farmers. RMA recognized the current information packaging is not based on farmers’ needs, whereas MINAGRI also questions the content of the early warning information received from RMA.

> *‘’ It is RMA that took the initiative of leading the production of the early warming information, but now we need more partners on board. First, we want to go on field and ask farmers what their needs are, then we will know how to better plan our services according to their needs. The current early warning information disseminated doesn’t communicate if the rain might cause flooding or not. This is something which will be achieved through the National Climate Outreach Forum, as we will be teaming up with hydrologist to predict the likeliness of floods (RMA representative, Kigali)*

> *‘’ We as MINAGRI are not involved in the production of the early warning information, we are among the users of the information. The current early warning message is questionable. The content of the message informs the farmers the measurements of expected rainfall (which farmers do not all understand), but doesn’t also communicate to them what to do (mitigation measures)’’ - (MINAGRI representative, Kigali).*

5.4.2. The use of received information in agricultural farming decisions

Forecast information can only be valuable if the users change actions in beneficial ways basing on the content of the information (Stern & Easterling 1999). The impact of forecast and early warning information can be evaluated by assessing whether or not farmers have changed their farming actions based on the received information. Most of the farmers interviewed reported having taken a number of farming decisions in one way or another (either short-term or long-term) referring to the received forecast information from different sources.

On one hand, it is important to note how farmers relate and connect their decisions and actions, with different types of forecast information (seasonal and daily forecasts were the mostly mentioned). The assessment of their responses on the taken actions and farming planning decisions included time of planting, crop choices, seed varieties choices, hiring extra-labour in the farm, when to apply fertilizers, time of harvesting. These decisions are mostly dependent on seasonal and daily forecasts.

Although the majority of farmers indicated not receiving the seasonal forecast information, a few of them (all men) who received the information from meetings organized by RAB and RMA, reported it as being a crucial factor in planning and making their long-term decisions on when and what to plant. Farmers relate the vulnerability (to heavy rainfall events) as changing depending on the planting time and choices of crops / seed varieties. Here is what one of the interviewed farmers had to say on the influence of seasonal forecast information on the sowing/planting time.

> *‘’Normally we plant potatoes in February, but when the seasonal forecast show that February, March and April will be characterized by heavier precipitation than normal, then I know that I might face yield losses. In that case, I am obliged to rather plant potatoes in early April, because then I know that even if it rains a lot in April, it will be less in May, and in that case I always expect a good harvest in July, thanks to a combination of a balanced water distribution and rain between April and July’’ (Male farmer, Musanze District)*

Similarly, all farmers from Nyabihu District I interviewed, had been assisted by the USAID-funded ‘’Rwanda Climate Services for Agriculture’’ Project, and have been trained in the Participatory Integrated Climate Services for Agriculture (PICSA) approach. PICSA is an approach that has been developed by the University of Reading and has been supported by CGIAR Research Programme on

Climate Change, Agriculture and Food Security (CCAFS). PICSA approach seeks to facilitate farmers to make informed decisions based on accurate, location specific, climate and weather information; locally relevant crop, livestock and livelihood options; and with the use of participatory tools to aid their decision making (Dorward *et al.* 2015). All of them reported using forecast information in making choices over the adoption of crop or seed varieties, basing on the predicted seasonal forecast.

> *‘’The information helps us knowing which type of potato variety to use. Peco variety is not resistant to heavy rainfall compared to the Kinigi variety, therefore I often use Kinigi thanks to the seasonal rainfall prediction (Male farmer, Nyabihu District).*

> *‘’ When we are informed that we are going to have a shorter rainy season, I select the potato seed variety which grows faster, so that I can harvest before the dry season comes (Female farmer, Nyabihu District)’’*

The Post-Harvest and Agribusiness Support Project (PASP) is an IFAD-funded project implemented by MINAGRI, focusing mainly on reducing post-harvest losses caused by climate change and variability. One of its components is to promote the adoption of crop varieties that are more resistant and suitable for environmental and climatic challenges in 12 districts including Musanze and Nyabihu. A PASP representative I interviewed, indicated working with RMA and RAB on deciding which resistant seed varieties to suggest to farmers.

> *‘’We work hand-in-hand with RMA (for accessing the forecast information) and RAB (for research on crop varieties resistant on droughts and heavy rains). The aim is to distribute seed varieties based on the rainfall prediction. For example, some potato varieties are more resistant to heavy rainfalls than others (PASP Representative, Kigali)’’.*

However, as communicated by a representative of the ‘’Rwanda Climate Services for Agriculture’’ Project - RCSA, it is important to note that the project’s assistance is limited to assess together with farmers what could be the best decision to take, according to the predicted seasonality changes. Farmers are the ones with a last say on if it is worth taking a decision or not.

> *‘’At least 2 months before the seasonal forecast is out, we base on the historical data from the Meteo Rwanda Map Room (http://41.74.170.130/maproom/) to inform farmers on the planting time, ahead of the seasonal forecast. After trainings, a farmer can decide to*

change crops, plant earlier or even to shift to another income-generating activity, depending on the information provided in the seasonal forecast. For cooperatives, the same training is provided, and decisions are taken on a cooperative level'' (RCSA representative, Kigali).

On the other hand, a good number of respondents claimed to use the received daily forecasts in making short-term decisions to avoid losses in terms of money, agricultural inputs or post-harvest losses. These decisions are related to a better planning of everyday's farming activities and include hiring extra labor, harvesting, and pesticide application.

> *''Getting daily forecast, helps me to better plan my day to avoid unnecessary expenses. For example, when am about to hire extra labour on my farm, I have to check the weather, otherwise if I invite them and it rains, I have to pay them'' (Male farmer, Nyabihu District).*

> *''In the past years, we used to be surprised by rains when we were harvesting, which always made our potatoes produce rot. Nowadays when it is time to harvest potatoes, I rely on the daily forecasts. I only harvest on a sunny and dry day, to make sure my produce reaches the market being still in good conditions. The same is applied to potato seeds: you cannot store them in wet conditions'' (Male farmer, Musanze District).*

> *'' Of course, when I know it is going to rain during the day, I cannot apply the pesticides otherwise they will be washed away by rains'' (Male farmer, Musanze District).*

The majority of farmers need 3-months forecasts (seasonal forecasts) the most but insisted that seasonal forecasts should communicate the onset and cessation of rains, for farmers to be able to take farming decisions like planting date or choosing crop varieties. Farmers indicated that not being able to receive seasonal forecasts or receiving inaccurate forecasts, results in huge crop losses.

However, some farmers (including almost every woman interviewed) do not trust the received information and therefore don't incorporate the information in their agricultural planning and decision-making, for numerous reasons including religious beliefs and/or judging the information as inaccurate.

> *''The information accuracy is so dubious. Sometimes, it rains as forecasted but often times the forecasted information says it will rain and we never have the rain, or it rains on another day other than the one*

communicated. Due to these inconsistent changes, I cannot make any decision relying on it'' - (Female farmer, Musanze District)

''You know, as humans we have different beliefs. Many of us do not believe in the information just because we know and believe that only God can control everything including the weather. Personally, I also doubt the information, these people who prepare this information are also humans and can make mistakes. It is really difficult for me to immediately value the received information and therefore it would be hard for me to base on it and make farming decisions'' - (Female farmer, Nyabihu District)

Some of these farmers feel the need of improving the content and dissemination of the forecast information, particularly the quality, timing and localization-specificity (to be elaborated more in section 5.5.), which leave some of them preferring to rely and use the traditional indigenous knowledge in predicting the weather and taking their short-term farming decisions.

''I also use my traditional knowledge in making some short-term decisions. By looking at the changes in the sky, I can see that it will rain. It is something that we rely on as farmers, although it is mostly used by old farmers as the young people don't have the knowledge. (Male farmer, Musanze District).

These needs and trust levels towards different types of forecast information and will be explored more deeply in the next section 5.4.

Regarding the flood forecasting and early warning information, farmers reported that they never received it. However, some even questioned the direct impact it would make: some of respondents indicated that for most of the times, communicating flood forecasts when they had already planted crops, will lead to no action that could reduce the losses associated with heavy rains and floods.

5.5. Trust and reliability in the weather forecast information

The adoption and use of official weather forecast knowledge in making informed farming decisions depend on the trust one has towards the weather forecast information. The low trust is caused by several factors including the accuracy of the weather forecast information, the indigenous/traditional knowledge, the religious beliefs, etc. on rainfall variations and adaptation strategies. All these factors will be discussed one by one in this section, with a more detailed analysis of the indigenous knowledge in the last two sections.

5.5.1. Challenges in trusting the weather forecast information

Although the majority of farmers use the weather forecast in agricultural planning, they still find challenges in the quality and accuracy of the forecasted information. I asked farmers on their levels of trust in the weather forecast information in general and more specifically on different types of weather forecasts received. Their responses were variable from one type of forecast to another, due to numerous reasons including mainly the accuracy of the information, but also their perceptions on understanding forecast accuracy, their past experiences with weather forecasts, and finally their capabilities in interpreting correctly the weather forecast terms.

Firstly, farmers' trust is much more dependent on the accuracy of the forecast information and this differs from one type of forecast to another. All farmers receiving weather forecasts believe, the information is not properly location-specific and feel the need of downscaling it from the district to the sector-level. The current forecasts are targeted on a district-level and farmers face diverse uncertainties, as the district is huge.

> *''The district is too big, getting information on a sector-level would be more beneficial, and will even increase farmers' trust in weather forecasts'' (Male farmer - Musanze District).*

From farmers' responses I realised that farmers' trust decreases from short-term to long-term forecasts. Generally, farmers believe the daily forecasts are more trustworthy than monthly or seasonal forecast. However, they also still find challenges in the accuracy of daily forecasts. Their trust in short-term forecasts (1-3 days forecasts) is conditioned by how accurate the weather forecast information is, in terms of being more location specific. In short, more geographically localized information = more trust! The RMA staff I talked to indicated that the accuracy of daily and seasonal forecasts is estimated to between 85-90% and around 75% respectively. However, farmers perceive that daily forecasts are not localised enough as communicated (through SMS, USSD, radio and many other dissemination channels), a fact that even RMA recognizes. Daily forecasts are covering the entire district level. However, farmers and key institutions believe the geographical coverage district is too large and makes the forecasted information inaccurate to the locality. Farmers in different sectors of the district experience different types of weather (having all received the same weather forecast) and this reduces their trust in the weather forecast from RMA.

''I am not really satisfied. The most challenging issue for us who live nearby the volcanic region, is that the information forecasted is not localised enough. Consequently, we experience different types of events within the same district, as the district level is too large'' (Male farmer, Musanze District).

Secondly, trust is affected by the lack of general knowledge on weather forecast information and how it is designed. Some farmers expect the forecasted events to happen exactly as communicated, and do not know that it is subject to some changes sometimes. These farmers have lost trust and never rely on the modern forecast information. However, the majority of them (especially those from Nyabihu District who have received PICSA trainings) understand the uncertainty factors behind the forecasted information and estimate their percentage of trust at the levels of 70% and 80%.

'' It is of course not 100% accurate, and that's why even by the name it is called ''iteganyagihe'' (translated into a forecast), but even if it doesn't exactly rain on the same day or same hour as predicted, at least we see the signs of rain, and you realize it will probably rain in few hours coming or the following day'' (Male farmer, Nyabihu District)

''I estimate my level of trust towards the weather forecast information at 80%. Thanks to the trainings we received, I know it cannot be 100% because it is just a forecast (Male farmer, Nyabihu District)''

RMA also believes the trust levels have been improving in regions where farmers are trained on the uncertainties involved in the occurrence of weather events in contrast to how they are predicted. These regions include my area of study (North-Western Rwanda) but also some of the Southern District regions.

'' The trust is improving, but not yet at the level we want. Farmers trust the weather forecast information differently. In some regions, trust is high in some others very low. From the feedback we get, we realised that 80% of farmers in the North-Western districts (Rubavu, Musanze, Nyabihu, Ngororero) are trusting the weather forecast information than before. It is also the same for the Southern Districts (Nyanza, Nyamagabe, Gisagara). These improvements result from the discussions and trainings we have with farmers. We explain to them the role of the meteorological information, but also how weather forecasts are just predictions susceptible to changes anytime. Most of these farmers have understood that weather events don't occur 100% exactly as predicted'' - (RMA staff, Kigali).

Also, as covered in the last section, the lack of trust in the weather forecast and early warning information is driven by some farmers' (all women) beliefs basing on the fact that God's divine power controls weather. All women farmers indicated having not more than 50% of trust towards the weather forecasts.

> *''I trust the information at a 50% level, because I know it comes from high-tech instruments made by human beings. As human beings, we are not God, so we can make mistakes. For that reason, I cannot trust it at a 100% level, because it is just a forecast''*
>
> *''Because as humans we have wishes, but only God decides what happens, I would estimate my trust at 50% (Female farmer, Musanze District)*

Lastly, the past experiences of less accurate weather forecasts continue to play a role in the mistrust of the weather forecast. Although some farmers believe in the current years, the accuracy of the weather forecast information is increasingly becoming more and more accurate, some are still recalling the information they were receiving in the past 10-15 years which were inaccurate and less credible to rely on in farming. These are mostly old farmers who from that time onwards generally seemed to not be convinced by the modern science forecasts. Most of them prefer to rely on traditional or indigenous forecast knowledge, as they claim it is just risky to rely only on the forecasted weather information.

5.5.2. The role of indigenous knowledge

''By looking at the changes in the sky, I know if it will rain or not. Let us not underestimate this knowledge. Even Jesus recognized in the bible the capacity of humans in predicting rain after seeing a cloud rising in the west'' - (Male farmer, Nyabihu District).

For years, the indigenous knowledge has been in the traditions of smallholder farmers**.** During the individual interviews and focus group discussions, I realised that many farmers (mostly older ones) still value and believe in the use of their indigenous knowledge to predict the onset and cessation of rains, as well as other changes in the climate. When conducting individual interviews, some farmers indicated relying on their indigenous skills of weather forecasting, claiming it is also accurate and more relevant to the local situations. Wind direction, changes in the sky, animal behaviours (the appearance of insects such as ants and termites), and change in human body feelings, are some signs that old farmers from both districts indicated were using (or still use) to understand and predict weather changes on the local context.

''I use more my traditional weather forecast knowledge, in predicting the seasons than daily. To explain more on this, I see the current seasonal changes and by comparing them with my old knowledge of how the seasons used to be, I can make a long-term decision on my farm'' – (Male farmer, Nyabihu District)

<u>Animal behaviour</u>

The behaviour of certain types of animals as well as the wind direction were perceived as a highly reliable indicators of possible rain, although it seemed to be known by a few farmers from both districts

''Before we could know the rain is near, by checking the animal behaviour: ants coming out from holes, butterflies flying, birds like egret or others of around 300 per group flying together'' - (Male farmers / FGD participants - Nyabihu District)

''Some farmers in our community can predict rains, just by assessing the cow's health status'' - (Male farmer / FGD participant - Musanze District).

<u>Wind direction</u>

''When the wind moved back from the east to the west (having first moved from the west to the east), it always came back with rain in the next 1-2 days. The interval between the two winds could vary, but the official confirmation, was that on its way back from the east to the west, the wind was always cold. Farmers believed this and it was always accurate. To detect which direction the wind was taking, we were referring to the leaves of trees in the forests''- (Male farmer / FGD participant – Musanze District)

<u>Human body feeling</u>

Another indicator highlighted by both Nyabihu and Musanze farmers during focus group discussions, is the change in human body feelings of excess heat, a few days before the rain occurrence.

''The feeling of an excessive heat (which is not common in a mountainous region where we live) especially during the night, with a lot of sweating, is also a sign of an imminent rainfall (Male farmers / FGD participant - Nyabihu District).

''Some people who suffer from chronic respiratory problems (mostly asthmatic) always become sick whenever it is going to rain, after a long dry

period. Among other symptoms we also have headaches and flu'' - (Female farmers / FGD participants - Nyabihu District).

Other rainfall indicators

Additionally, Musanze farmers added other indicators, including using a clay water pot and checking water levels

> *''To predict the occurrence of rainfalls, the traditional rain forecasters (abavubyi) were taking a clay water pot on top of a high mountain and reverse it. They could go back there on different days, constantly checking the changes of humidity inside the clay water pot. Once they could see the inside becoming more wet, then they could predict that the rain is near. That is why I am confirming that these traditional systems could also work, because it has been working perfectly in the past (Male FGD participant - Musanze District).*

> *''When I was still young, our parents used to also check the water levels in rivers and lakes. As the levels went high, we would know that it was raining in the closest areas, and we were expecting the rain in our area as well'' (Male FGD participant - Musanze District).*

During FGD, I realised that young farmers have a considerably low trust in the traditional weather forecast knowledge compared to older farmers. Young farmers were convinced the traditional forecast systems are not reliable. However, old farmers also agree with that but stressed out that it should not be neglected completely. In the end of what seemed to be a long debate between them, they all agreed that combining the two types of forecast (conventional and traditional) could be a long-lasting solution to more accurate weather forecasts. Young farmers also expressed the need of being taught the indigenous knowledge by their parents.

> *''The solution should be to combine the two types of information. What we don't want is people telling us that the modern technology-based weather forecast is the online reliable information, that our ancestors did not know how to think and predict. To that we say no, no and no. We have so many examples of when the modern technology-based weather forecast disappointed us (Male farmer, Musanze District)*

> *''Thanks to my grandmother, I know some rainfall prediction indicators. She is the one who taught us the little I know. However, I still want to learn more on how to predict the weather using the indigenous forecasting skills'' (Young male farmer, Musanze District)''.*

5.5.3. Effects of climate change and variability on the indigenous knowledge

However, although these farmers listed all those indicators, they also feel the use of local or indigenous weather forecast knowledge, is currently challenged by climate change and variability. One farmer from Musanze District indicated that some signs are no more appearing like how they used to see them because of a changing climate.

> *‘’I no longer rely on the traditional forecast knowledge like before because the seasons have changed! I prefer the modern weather forecast information broadcasted by the radio (Male FGD participant, Musanze District).*

> *‘’Climate change and variability is a threat to the traditional weather forecast knowledge. For instance, we were used to waking up and see snow on top of Karisimbi (the highest volcano in Rwanda, 4507m). Before the appearance of snow, clouds always started covering the volcano, and residents of Mutura sector (close to the volcano) could tell us that the rain is soon, and it always happened as predicted. Nowadays we no longer see snow on Karisimbi, and it is just a confirmation that the climate is getting hotter and hotter’’ - (Male farmer / FGD participant - Musanze District).*

The debate on the indigenous knowledge was more interesting in the focus group discussions, as young farmers kept on challenging the older farmers, on the accuracy of the indigenous knowledge, claiming that the accuracy of the indigenous knowledge is not reliable.

> *‘’I personally think, the winds are not an indicator to rely on. Currently from what I see, most of the times strong winds actually chase away the rainfall probabilities, even if the sky was showing the signs of an upcoming rain’’ - (Young male farmer / FGD participant - Musanze District).*

> *‘’These signs and indicators become only accurate when we know it has not been raining for some days/months. You cannot apply them every time, especially in the middle of the rainy season (Young male farmer / FGD participant - Musanze District).*

5.5.4. Which one to trust? Indigenous knowledge or scientific weather forecast information?

On which type of information to prefer between indigenous knowledge and the modern-based weather forecast, farmers in FGD expressed different views, however the majority think the modern weather forecast knowledge could generally be more reliable, if only there were improvements in its accuracy.

> *‘’Even if I once in a while use my traditional knowledge, I know it is not more reliable than the modern forecast, mainly because with the traditional knowledge you can predict the sudden changes that may occur later on the day, but with the modern weather forecast technology, the forecast changes are communicated to us via SMS’’ (Male farmer - Musanze District)*

> *‘’It is true that some farmers rely on it, but it is not accurate than the technology-based forecast, and also it provides a forecast for only one day, not for 1 week or for 1 season. How can you predict a seasonal forecast by just looking up in the sky? It is impossible (Male farmer - Musanze District)’’.*

I tried to ask RMA if they ever integrate the indigenous knowledge in the production and design of the modern weather forecast systems. However, this indigenous knowledge is not documented neither is not sensitized.

> *‘’RMA doesn’t sensitize farmers to not use the indigenous knowledge indigenous. They only advise them to use the modern info, but without forgetting the indigenous knowledge’’ (RMA staff – Kigali)*

6. DISCUSSION

In this section I discuss how farmers' perceptions on the vulnerability of their farms, the coping measures taken against the heavy-rain hazards, and the influence of farmers' awareness and understanding of climate change and variability. The Protection Motivation Theory (PMT) will be used to show if there is any significative association between farmers' capacities of assessing the threat and coping appraisals, and their abilities and motivations to protect their farms from future heavy rain hazards. Later, it specifically analyses the role of the weather forecast information in informed adaptation decision making, referring to the DOI theory.

6.1. Farmers' perceptions on the farming vulnerability and severity of heavy rainfall hazards and seasonality changes

Referring to PMT (see section3.1.), the threat appraisal is explained as including the perceived vulnerability (or the person's perception of being exposed to a certain risk which will harm him/her and/or his/her belongings) and the perceived severity of threat (or in other terms, a person's perception on the harmfulness of the threat on his/her property and other valuable things).

This study has shown that most farmers have consistent levels of awareness of and perceptions on the danger of increasing heavy rainfalls, their related risks and impacts on small-scale farming. To recall the exact time of occurrence of past heavy precipitations events, farmers kept on referring to the impact those events caused on their farms.

On one hand, as seen in section 5.1.3. & section 5.2.1., farmers' perceptions on the vulnerability and (probability) likelihood of heavy rainfall hazards, included seasonality changes (characterized by the occurrence of more unpredictable rains), hydrological factors, the human activities that destroy the nature (like deforestation), the excessive exploitation of farms with poor land management practices and poor crop farming techniques.

On the other hand, the manifestation of the severity of heavy rain threats pointed out by farmers show that they understand the harmfulness and consequences of intense rains. Their responses on perceived severity include soil erosion which causes crop destructions, plant diseases, and the run-off of agricultural inputs like chemical fertilizers and pesticides, as seen in section 5.1.2. All these were shared by farmers as factors aggravating the seriousness of heavy rainfall threats.

6.2. Comparison between farmers' perception on rainfall changes and observed rainfall data

Several studies carried out in sub-Saharan countries revealed contrasting perspectives between farmers' perceptions of changes and the observed precipitations (Kosmowski *et al.* 2017). Similarly, in this study, it was difficult for farmers to recall with a great precision, the exact occurring time for the past rainfalls, as seen in (see section 5.2.2). Generally, it was not easy for them to make a comparison between the rainfall patterns experienced 10-20 years and the recent ones. As they do not keep rainfall records, to recall past rainfall patterns, farmers based their perceptions on the harmful effects of past rainfall patterns on their farming.

Farmers assessed the rainfall harmfulness as caused or influenced by an increase of rainfall intensity and the seasonality changes (changes of onset and cessation dates of rainy seasons). However, on the question concerning whether the farming vulnerability to heavy precipitation events is either regressive or progressive, farmers had different views on this comparison, but generally the majority of them perceived the current rainfalls as less harmful than those experienced 10 years ago and before, not that rainfalls did reduce but rather praising government efforts of soil erosion control and water management, as the main reasons behind the reducing harmfulness. Other farmers found the current rainfalls as more harmful: they feel there has been an increase of rainfall amount and intensity, claiming that they experienced the most devastating rainfalls in the period 2014-2016.

From the historical rainfall data observed at Rwankeri_Nyabihu and Ruhengeri_Aero_Musanze stations, it is evident that there has been a significant increase of annual precipitation in Nyabihu and a non-significant decrease in Musanze, over the period 1981 – 2017 (see figure 3). In Musanze, there has been a significant decrease in the number of days with rainfall amount greater than 15 mm over the period 1981-2017. However, this doesn't mean that the rains were not intense. The rainfall intensity might have been increased, even when the number of wetter days with rainfalls ≥ 15 mm has decreased. On the contrary, there was no significant anomalies of the rainfall data for the period 2014-2016, a period some farmers had indicated as having been characterised by the most devastating rainfalls. The values of annual precipitation and of the number of wetter days with rainfalls ≥ 15 mm during 2014-2016, were found as not being the highest over the period 1981-2017.

On the other hand, the majority of farmers claimed that they are experiencing a change of rainy seasons. Results from Figure 6 and Figure 8 revealed that cessation dates of SOND season have been changing from 2003 and 2004 in Musanze and Nyabihu respectively, affecting the alternation of crop seasons and confirming that farmers have a good perception of seasonality changes.

Since farmers responded to the question of changes in rainfall patterns referring to the harmfulness of rainfalls, which implies looking at rainfall data as well as the sustainable farming practices, it is difficult to make a general conclusion basing only on the correlation between observed rainfall data and farmers' perceptions. However, it true that there have been an increase of annual precipitation in Nyabihu, as well as changes of seasonal rainfall patterns, with regards to the alternation of the onset and cessation dates of rainy seasons in both Nyabihu and Musanze.

6.3. Preparedness and protection measures

To effectively design and implement adaptation strategies, it is important understand the individual farmers' perceptions of climate change and vulnerability, and their influence on their decision-making (Eitzinger *et al.* 2018). The awareness of climate change is one of the elements that can be important drivers of the adaptation decisions. This study revealed that most farmers are adopting various practices in the face of climate change and variability, specifically the occurrence of heavy rainfall-related risks.

Farmers' capacities to engage in adaptive actions and behaviours are shaped by their knowledge, beliefs and attitudes on climate change and variability. Basing on the previously shown results (See chapter 5.2.) on the knowledge of climate change and variability, and referring to the PMT theory, perhaps one could make two categorizations of farmers. The first category is for those who proved to be aware of the potential causes of climate change and variability (specifically the occurrence of changing rainfall patterns). These are farmers who also showcased high capabilities of threat appraisal and coping appraisal as per PMT. They demonstrated high willingness to adopt some adaptation practices more than other farmers, and favoured practices including mainly hillside terracing, planting on time, fallow farming, anti-erosive ditches, bamboo planting, land rotation, crop rotation, off-farm activities and construction of gabions amongst others. These practices can be classified among adaptive or protective responses as per PMT.

However, there was also another category of farmers who (for the majority of cases were women) tend to connect climate change and variability with religious beliefs, seeing the occurrence of heavy rainfall hazards as God's punishment and/or divine anger.

These beliefs can impact negatively farmers' self-efficacy and protection. Self-efficacy is explained as a person's belief that he or she is able to effectively adopt the recommended actions (Cismaru *et al.* 2011). Seeing climate change and variability as caused by God's will or anger / punishment, will perhaps decrease farmer's self-confidence in their capacities to deal with the hazards. However, for my case, I did not study deeply how the impact of these religious beliefs in the protection and adaptation in general, to claim that there is any correlation between those beliefs and the adopted protective measures.

6.4. The role of trust in adaptation strategies

Also, as suggested by Westcott *et al.* (2017), trust in the agencies delivering adaptation or emergency services (in our case the government institutions) can positively affect the coping mechanisms. In my case I found that most farmers have trust in adaptation strategies initiated or supported by the government. For instance, the hillside terracing is highly praised by farmers and is perceived as a practice bringing positive sustainable farming outcomes.

Additionally, as suggested in other studies, like the one in Vietnam (Phuong *et al.* 2018), farmers' participation in social activities is very important in facilitating knowledge and information-sharing among farmers on the new trends of vulnerability and coping measures. In our case, farmers' participation in ''Umuganda'' community work (see section 5.3.) has proven to shape farmers' knowledge, with the aim of reducing uncertainty by bringing together people, to find collective solutions of mitigating hazards as explained by Westcott *et al.* (2017). This results in improved self-efficacy (Cismaru *et al.* 2011).

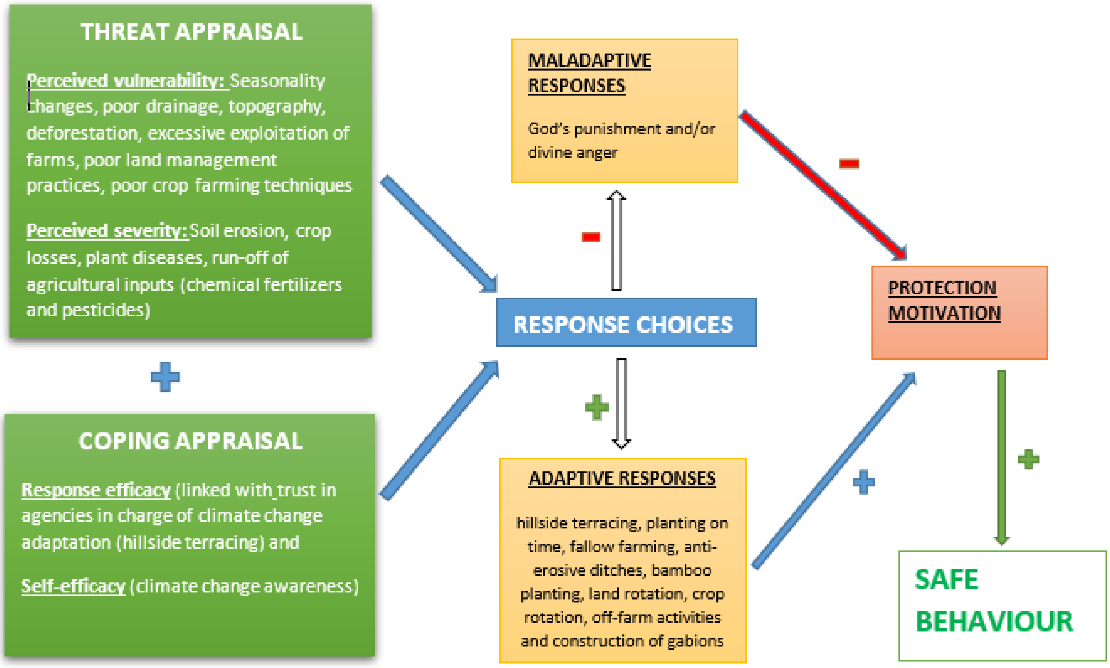

Figure 15: Applying Protection Motivation Theory in adaptation to changing rainfall patterns (Adapted from Westcott et al. 2017)

Other barriers

While farmers seemed to be confident with most protective measures and adaptation activities adopted, there are some barriers to adaptation in relation with the variations of onset and cessation dates of rainy seasons. Interestingly, even though most farmers mentioned seasonality change as one of the main factors aggravating their farming vulnerability, farmers do not link it directly with the accessibility of weather forecast and/or early warning information among the coping measures. However, by indicating planting on time as a prerequisite and starting point in climate change adaptation, one could understand that farmers indirectly communicated the need of getting information on the changes in seasons ahead of their sowing. Not listing seasonal prediction or weather forecast information among adaptation strategies, is a lack of knowledge on whether such information exists or for those who know it exists, ignorance on its contribution in creating more resilience against weather shocks. This will be explored more in the following sub-section 6.5.

Also, farmers' responses did not include what should be their roles in treating the hydrological threat, like the water coming from the volcanoes' rivers. Their responses were limited on the farm level's actions, yet they mentioned it among the main flooding threats. Reasons behind this could be many, probably because they feel there is nothing that can be done to channel this water as some said or may be because they feel it is a government responsibility as the other farmers indicated. Nonetheless, the hydrological and meteorological parameters are intertwined and they are all to be considered in resolving the long-term vulnerability risks associated with changing rainfall patterns in volcanic region.

6.5. The role of weather forecast information in adaptation decision-making

Basing on the DOI theory, in this chapter, I am analysing the perceptions of farmers and other key stakeholders, on the various factors affecting the adoption of weather forecasts in making climate-informed decisions. The DOI theory builds its foundation on the assumption that an adoption of an innovation is dependent on how individuals perceive the said innovation (Rogers 1983).

6.5.1. Weather forecast information as an innovation

According to DOI theory, an innovation is ‘’an idea, practice, or object that is perceived as new by an individual or other unit of adoption’’ (Rogers 1983). I could not find any official document stating the exact year the dissemination of the weather forecast information started in Rwanda, however an official of RMA told me that the year 2015 is when they started to send out the forecast information to farmers in a regular and professional manner. Before that time, it was done on irregular occasions (Mbati 2019). Weather forecast is therefore considered as an innovation, being still perceived as new by farmers, who for so many years, have been relying on their traditional knowledge to predict weather changes. Using DOI theory, I refer to five key elements of innovation (relative advantage, compatibility, complexity, trialability and observability) to analyse the probabilities of adoption and/or rejection of the technology-based weather forecast information as an innovation). This means understanding at what extent the weather forecast technological information is perceived as better than their traditional forecasting knowledge, on which level it is fitting within the values, experiences and needs of the farmers’ community. I also looked at the weather forecast information’s ease of use, the testing of its applicability and whether or not its successful results can inspire future potential adopters.

<u>Perceived usefulness: Relative advantage and compatibility</u>

- Relative advantage: Despite some farmers who are still doubtful and hesitant on using the technology-based weather forecast information, generally the technology-based method has a slightly higher relative advantage than the indigenous weather forecasting methods. Most of farmers find it as more advantageous than the traditional/indigenous forecast knowledge. Even older farmers, believe the applicability of traditional forecast knowledge is limited to a shorter period, and therefore would prefer the technology-based information, if provided with more and better accuracy (see section 5.4.1).

- Compatibility: For an innovation to be easily adopted it should fit in the existing culture, values, past experiences and needs of potential adopters (Rogers 1983). Incompatibility was found in mostly women farmers who cannot adopt the forecast information due to religious beliefs (see section: 5.3.2.). Another form of incompatibility that was found with regards to past experiences, is that indigenous forecast information was always gathered through viewable and sensible nature observations like change in the skies, or wind directions, and transmitted orally from one person to another (see section 5.4.2.), which the weather forecast services do not provide at the moment.

Ease of use versus or complexity

As per the third element of the DOI theory, the simplicity or complexity of an innovation influence the likeliness of adoption of a technological innovation. During both the individual interviews and focus group discussions, farmers found it difficult to understand and interpret the received information, questioning the content and terminology of weather information. For instance, from the received text-based messages weather forecasts, farmers find it difficult to understand the rainfall measurements in millimetres, or the high/middle/low clouds (see section 5.5.2). Referring to Rogers (1983), either farmers' knowledge or the simplicity of the weather forecast information plays a key role in the ease of use and overall adoption of weather forecast information. For the example shared above, it is undoubtedly linked with a lack farmers' knowledge on the rainfall measurements, and the real meaning of forecast terms like cloud formations used in weather prediction.

Trialability: Testing the applicability

The main objective of innovation trialability is to be able to test it on a small group of people, before enlarging the implementation to a larger group. In this study I found out that there are ongoing trainings (PICSA amongst others), aimed at strengthening the capacities and knowledge of Nyabihu farmers in understanding and analysing climate information, guiding them to make informed farming decisions, suited to the weather and climate conditions. These capacity building programs are coordinated by many stakeholders including the Rwanda CSA Project, RMA, PASP project amongst others. The success of such initiatives should be measured in how much they are able to reduce the uncertainty of future potential adopters, through practices capitalizing on the experience of the current adopters. As Rogers (1983) said: ‘’An innovation that is trialable, represents less uncertainty to the individual who is considering it for adoption, as it is possible to learn by doing’’.

Observability: Are there successful results that can inspire potential adopters?

Observability is defined as ‘’the degree to which results are visible to potential adopters’’ (Rogers 1983). Generally, it was not by random that the wealthier farmers, whose farming generate more income than others, have a better understanding and access to weather forecast information. These farmers are considered as role models by other farmers, who expressed both a conviction and/or institutive feeling that, part of their role models’ success is linked with the easy access and use abilities of the weather forecast information. These farmers clearly communicated an aspiration of becoming like their fellow successful farmers, by improving their knowledge on the weather forecast information.

Uncertainty

The use of the forecast information is challenged by the trust of farmers towards the level of accuracy of the information disseminated. Farmers’ lack of trust is one of the root causes of a low adoption and use of the weather forecast information services. The low accuracy of information could be classified among what Rogers (1983) classified as consequences an innovation. It is important to study and inform individuals on the advantages and disadvantages of an innovation, to make them aware of its potential consequences (Sahin 2006). On one hand, weather forecasting uncertainty is not communicated in the disseminated information, and I suspected that most farmers questioning the accuracy of information, are the ones expecting the forecast events to happen 100% exactly as predicted. They are not informed that the weather forecasts always come with a degree of uncertainty.

On the other hand, it is true that the forecast information is confusing farmers sometimes, in terms of its timeliness and geographical specificity. Most farmers perceive and explain this poor accuracy, with the fact that weather forecasts are not location-specific enough, therefore not always reliable.

6.5.2. Communication channels

Weather forecast and early warning information can be valuable to risk reduction initiatives and mitigation measures, in face of changing rainfall patterns, only when they can be easily accessed. In this study, I found out that the type of dissemination channel used, influences the information reach, the type of weather forecasts and adoption possibilities.

Mass Media channels

Similar to DOI theory assumption that mass media channels (radio, television, newspapers) are rapid and efficient in transmitting information to a big audience of potential adopters (Rogers 1983), I also found that the radio broadcast are very popular, highly rated and perceived by farmers as efficient climate awareness tool, for being easy to use and access weather forecasts. The challenging aspect is that most of the farmers just follow the radio broadcasts occasionally which means they often miss out on the right time of broadcasts, and unfortunately the forecasts are not repeated regularly throughout the day. With regards to other mass media channels, television is not owned by many although those who own it rate as highly effective and there was no mention of using newspapers in receiving forecast information. Radio and television are used to disseminate both short-term forecast (1 to 7 days) and long-term forecasts (1 to 3 months).

Interpersonal channels

Interpersonal exchange of information is more efficient in persuading individuals to adopt an innovation, especially when there is a high degree of resemblance between the transmitter and the recipient of information (Rogers 1983). On a very few occasions, farmers who are more knowledgeable (through trainings) can brief others on expected weather variations, but generally, this type of communication channel is almost non-existent. The main cause appears to be linked to a lack of knowledge and interpretation skills on the forecast information, as per the observations from MINAGRI (see section 5.3.1.1.).

Mobile phones (SMS and USSD services) and social media

Contrarily to the radio which broadcasts the information most of the times after the news bulletin, the dissemination of weather forecasts through the mobile phones via USSD / SMS is also beneficial in a way that the information stays longer and can be accessible at any time of the day. Unfortunately, this has also got hindrances: Firstly, not every farmer owns a mobile phone, secondly the USSD/SMS-based forecast information is not as detailed as on the radio, where farmers can ask questions during the radio broadcasts shows. However, with the increasing mobile ownership in Rwanda, I can argue that in the upcoming years, this type of communication channel has the potential to become a more important source of delivering weather forecast information than it is now. Statistics show that between 2000 and 2018, the number of mobile cellular subscriptions per 100 inhabitants shifted from 0.49 to 78.85 respectively (Holst 2019). This may also have an impact on the use of social media forums as important source of weather forecast information. The SMS/USSD is only used for a 3-day maximum weather forecast, whereas the information delivery on social media platforms combines both short-term and long-term forecasts.

6.5.3. Time

Rogers (1963) evoked time as involved through three main dimensions: innovation adoption process, innovation adopter categories and rate of adoption.

Decision process: adoption of weather forecast information

Forecast information can only be valuable if the users change actions in beneficial ways basing on the content of the information (Stern & Easterling 1999). From the discussion I had with a representative of PASP project, I understood that the role of institutions lies in packaging and dissemination of weather forecast information (sometimes also advising them on which decisions to make), however farmers remain with a last say on if it is worth taking a certain decision or not.

From getting the initial understanding of an innovation, to taking actions based on an innovation and evaluating results after taking decisions, Rogers (1983) described the innovation adoption as a 5-steps process (Knowledge, Persuasion, Decision, Implementation and Confirmation). Farmers also go through the same process.

While there were a few who expressed their first interest in wanting to see (for their first time) both how to check the information (dialling *845#), and the content of the information, using a mobile phone, generally the majority have passed the first step (Knowledge). Knowledge is a stage where the main objective is to seek a software information embodied within a technological innovation (Rogers 1983).

The second step ‘’Persuasion’’ happens when an individual assesses the advantages and/or disadvantages that the innovation may present to his/her work. An example here is with those farmers who have understood the importance of using seasonal forecasts in setting planting date (either early or delayed planting) while also recognizing some accuracy challenges associated with weather forecasts in terms of localisation.

In a third step ‘’Decision’’, an individual or other unit of adoption engages in activities that will lead to the adoption or rejection of the innovation (Rogers 1983). In our case this relates to those farmers, who have attended trainings / meetings on the use of weather forecast information in agriculture, or those making calls on radio and on RMA hotline.

The fourth step, of implementation relates to acting or making decisions based on the received information. Farming decisions made could be categorised basing on type of forecasts. Short-term forecast-based decisions indicated by farmers are mainly aimed at avoiding losses in terms of money (hiring extra-labour in the farm is done after checking daily forecasts), agricultural inputs (timing of pesticides application) and post-harvest losses (timing of harvesting). Long-term forecasts include time of planting, crop choices, and seed varieties choices).

The fifth step ‘’confirmation’’ happens when an individual or other unit of adoption seeks reinforcement about the innovation decision (e.g.: discussion with peers) (Rogers 1983). This means evaluating changes resulted from innovation-based decisions made. No interviewed farmer mentioned initiating an evaluation of results with stakeholders, however there is a top-down feedback mechanism initiated by RMA and RCSA project and carried out by journalists to farmers, seeking to understand their level of appreciation and satisfaction of the climate information services.

Adopter categories: Who is ready to use weather forecasts?

Rogers (1983) defined innovativeness as ‘’the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than the other members of the system’’. He categorised the adopters into five groups: innovators, early adopters, early majority, late majority and laggards. Below I applied the same categorisation on the empirical findings:

Innovators (*Venturesome*): These are people that are always seeking new ideas and are interested in trying new things (Rogers 1983). They adopt an innovation very early and play an important role in diffusing a new idea, importing it outside of the social system’s boundaries. I did not really find this category in my study population. According to Rogers (1983) innovators represent 2.5% of potential adopters.

Early adopters (Respectable) category includes those farmers who are more outgoing and are more localites than cosmopolites. They are among the first to adopt weather forecasting information in making farming decisions, and are respected by other farmers, who check on them before taking the same adoption decisions. This category represents a few farmers who access seasonal forecasts and claimed to have adopted them in planning and making their long-term decisions on when and what to plant.

Early majority (Deliberate) is represented by farmers with poor risk-taking attitude. They never want to be first, so they may deliberate for some time before adopting the weather forecast information. According to Rogers early majority group is represented by 34 % of potential adopters. This same percentage represents roughly the same category of those farmers who are yet to adopt and use weather forecasts into their farming decisions, until the accuracy is proven to be 100% efficient.

Late majority (Skeptical) group represents those farmers who are still doubtful of taking decisions basing on the weather forecast information (see section 5.3.2.). Their scarcity in resources like farm size, or communication tools (in our case radio, mobile phones, television), also contribute to their skepticism. They will adopt weather forecasting only when it has been approved to be beneficial by the large majority (Minishi-Majanja & Kiplang'at 2013).

Laggards (traditional) these people lag behind and are usually the last to adopt a new idea (Rogers 1983). Their point of reference is the past. It is difficult for them to adopt new ideas, because they always refer to past experiences. They therefore often connect with people with traditional beliefs and question the effectiveness of new ideas. This category includes mostly older farmers who don't know and don't want to learn how to access and use weather forecast information. These farmers are still relying 100% on their indigenous weather forecasting.

Communication behaviour

The interview questions did not respond to all the five variables of communication behaviour stated in the DOI theory (see chapter 2.3.3.) but two of them (knowledge and media communication channels) were found to be in line with the study results, having effect on the adoption and use of weather forecast information. Generally, the more sources of information farmers have access to, the more knowledgeable and action-oriented decisions they take. This is supported by the fact that different communication channels provide specific types of weather forecasts. For instance, as seen in section 5.4.1.1., farmers may receive seasonal forecasts on television or during community meetings, but never on mobile phones which provide primarily daily forecasts. Those receiving daily forecasts on mobile phones, will therefore end up taking only short-term decisions as seen in chapter 5.4.2. This confirms the DOI theory claim which states that earlier adopters are more exposed to media communication channels and have better knowledge of innovations than late adopters.

6.5.4. Social system

A social system is defined as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal (Rogers 1983). In this case, the social system is represented by different units including farmers, extensionists and key institutions that are involved in the packaging and delivery of weather forecasts for an effective. These include MINAGRI, MINEMA, RCSA project, PASP and RAB. For an innovation to be successful, it should be compatible to the structure, norms and leadership within the social system (Rogers 1983).

Social structure and diffusion of weather forecast information

Social structure is represented by how different units are arranged within the social system and can impede or facilitate the diffusion of innovation (Rogers 1983). The dissemination of forecast information is challenged by the lack of effective collaboration among institutions. However, the forthcoming National Climate Outreach Forum (NCOF) is viewed as an important platform to overcome this issue (see section 5.3.1.2).

On top of that, there is a recognition from institutions that the diffusion process is done in a top-down direction, therefore the next interventions should base on farmers' needs to ensure a forecast and early warning information with an effective content and terminology easily understandable by farmers (see section 5.3.1.2). Organisations are also convinced that to reduce the uncertainty in weather forecasts, it is important to localize enough this information, to be able to have a better impact.

6.6. The role of socio-economic factors

Although the interpretation of this study findings focused mainly on socio-cognitive factors (based on perceptions, beliefs) it is also important to show the correlation of the socio-economic factors (age, gender, farm size, location and education) with coping and adaptation strategies, and explore the relation with the socio-cognitive factors. Socio-economic characteristics (age, education, literacy, social status, size unit) play a crucial role in the adoption of innovation (Rogers 1983). I will be discussing the role of each of those socio-economic characteristics on the awareness of climate threats and coping practices, as well as on the adoption and use of weather forecast information.

6.6.1. Age

I found a correlation between an increase of age and risk mitigation awareness. Elderly farmers tend to know more about potential threats and coping and adaptation mechanisms like land conservation practices than young farmers, an assumption highly connected to their richer farming experience. On the other hand, age was not a significant factor in the process of adoption and use of weather forecast information. Earlier adopters did not differ significantly from late adopters in age.

6.6.2. Gender

With regards to percentages, 38.1% and 61.9% of interviewed farmers were female and male respectively. A consideration of gender perspectives revealed that generally, men understand the threats and causes of climate change more than women. From the empirical findings, it was evident that men know more about the causes of climate change and variability than women, however there was no significant difference between the two gender categories in the way they take risk mitigation responses.

Contrarily, although the DOI theory did not highlight the gender effect on the adoption process, this study revealed that gender plays a key role in the adoption and use of weather forecast information. I found differing levels of adoption between men and women with regards to the knowledge, trust and access to communication channels, as a result of gaps in digital divide, digital literacy and/or trust.

Firstly, digital divide is a challenge preventing an effective adoption of weather forecast information. The amount of information reaching farmers differs between those who have access to mobile phones and those who do not. Despite the increasing ownership of technological tools like mobiles phones in Rwanda (Holst 2019), many farmers (mostly women) still lack access to forecast information, just because they do not have mobile phones (see section 5.3.1.1). Basing on the fieldwork data, I realised that men receive forecast information through diverse communication tools as compared to women, and therefore have more access to forecast information than women. As an example, not a single woman indicated accessing weather forecast information on television (see section 5.3.1.1), probably because they are usually exposed to more home activities than men (KIT, Agri-ProFocus and IIRR 2012).

Secondly, the digital illiteracy is bigger in women's category: women tended to be less knowledgeable on how to check the weather forecast science and its terminologies than men, and therefore prefer getting the information on the radio.

Thirdly, women expressed low trust compared to men. Most of the women interviewed connect the poor accuracy of the forecast information, with their religious beliefs, indicating that the inability or difficulties of providing accurate information by responsible agencies, is a proof that human knowledge can never exceed God's will, therefore their low trust affects the possibility of taking informed decisions basing on the weather forecast information. Believing that only God controls the weather, often reduce their trust of the weather forecast, especially when the weather events do not occur as predicted (see section 5.3.2).

6.6.3. Farm size

Looking at the farm size, seven of the interviewed farmers do their farming activities on less than 0.5 ha, eight between 0.5 ha ≤ 1 ha, and six on a farm size between 1 ha ≤ 2 ha. On one hand, their responses were found to be equally distributed irrespective of the farms' sizes and/or districts regarding their vulnerability and the adopted climate-resilient activities on their farms.

On the other hand, this study found that, generally, farmers with larger farm size unit were proven to be using forecast information more than those with smaller farms do. This confirms the DOI theory assumption that early adopters have larger-sized units than late adopters (Rogers 1983).

6.6.4. Education

With regards to education, 57.1% had primary education level, and only 4.8% have attended university. Less educated farmers proved to be less knowledgeable on the causes of climate change than educated farmers. On the contrary, most of the less educated farmers had more farming experience and were found to be more knowledgeable of the vulnerability, coping and risk mitigation measures than some of the more educated farmers.

On the other hand, those who rely on the weather forecast information in making farming decisions, are more educated than those who do not, as per DOI theory which states that ''earlier adopters are more educated than late adopters'' (Rogers 1983).

6.6.5. Location

Location-wise, another important conclusion drawn from farmers' responses, is that Musanze farmers seem to know more climate adaptation practices than Nyabihu district farmers. This difference in the knowledge of climate adaptation practices per location was not studied, but perhaps that Musanze farmers being more close to volcanoes (and their rivers), are more exposed to flooding risks and therefore have been assisted and trained in protection and adaptation programs, more than Nyabihu farmers.

7. Conclusions and policy implications

This study draws upon qualitative and quantitative approaches to assess how adaptation to climate change and variability is influenced by small-scale farmers' perceptions on farming vulnerability to changing rainfall patterns, as well as the adoption and use of weather forecast information.

7.1. Summary of key findings

The results indicated that small-scale farmers in Musanze and Nyabihu districts perceive their farming is challenged by climate change and variability, characterized by the occurrence of heavy rainfalls and/or changes of rainy seasons. From farmers' perceptions, the harmfulness of changing rainfall patterns was interpreted as caused by changes in rainfall amount, rainfall intensity as well as variations in the onset and cessation of rainy seasons, but also influenced by the adopted sustainable farming practices. In spite of climate variability, it was noted that farmers have a moderately high level of awareness of climate change, but a moderate knowledge on the causes of climate change and variability. Farmers' perceptions on the causes of a changing climate are modelled by religious beliefs. Farmers' trust in government climate change adaptation initiatives was also proven to be high, as most of them claimed positive effects in reducing farming vulnerability.

In consideration of all these results, the study has shown that farmers' capabilities of knowing climate threats, the causes of climate change and variability, as well as their trust towards some of the government initiatives, possibly contribute positively to a well-timed anticipative adoption of climate-resilient practices. These include hillside terracing, fallow farming, anti-erosive ditches, bamboo planting, land rotation, crop rotation, off-farm activities, construction of gabions and planting on time amongst others. However, the contribution of each of these factors on adaptation was not studied separately.

To cope with climate risks and specifically deal with the impacts of changing rainfall patterns on small-scale farming, the study findings revealed that farmers need weather forecast information to be able to make informed farming decisions.

Most farmers access the weather forecast information through radio and mobile phones, a few other farmers on television, social media, during community meetings, and through information-sharing with other farmers. Long-term forecasting like seasonal forecast information was revealed to be more critical to farming, than any other type of weather forecasts, unfortunately only a few farmers access it. Short-term forecasts are also important in making decisions like application of fertilizers and pesticides, or when to harvest. The empirical results proved that the adoption and use of weather forecast information in farm-decision making depends much on the accuracy and content of information, communication channels, farmers' digital literacy and forecast skills.

However, while the scientific weather forecast information is generally perceived as having a higher relative advantage than the traditional forecasting methods, there are still barriers to its adoption and use in making informed farming decisions. These include low accuracy of information, lack of forecast skills, digital illiteracy, poor knowledge of the terminology used in weather forecasting, and a low trust towards the information which pushes some farmers in relying highly on indigenous forecast knowledge and/or on religious beliefs. The digital divide and digital literacy gaps were found to be deeper in women category. I suggest that the weather forecast information is designed and disseminated across time taking into consideration of the adopters' perceptions, needs and socio-economic characteristics.

7.2. Recommendations and further studies

Based on the findings of this study, there is a need of

- Sensitizing the community on the causes of climate change and variability
- Improving the content, accuracy and communication of weather forecast information, especially the seasonal forecasting.
- Training more farmers on the terminology used in weather forecasting.
- Targeting more women in initiatives aiming at improving farmers' climate and digital literacy knowledge and skills.

In line with the study findings, attention is drawn to the importance of conducting further studies on

- A quantitative research on the correlation between farmers' perceptions and adaptation capabilities per diverse regional backgrounds

- The exploration of changes in rainfall intensity and its effects on farming vulnerability, since in this study I only touched upon the amount of precipitation and seasonality changes data
- The traditional weather forecast knowledge to find possibilities of integrating it with the scientific weather forecast information, because as it was explored, some farmers still perceive it as essential in adaptation climate change adaptation mechanisms.
- The comparison of smallholder farmers' perceptions of climate change with observed meteorological data, taking into account other climate trends like temperature, not only precipitations as it was the case for this research.

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Appendix 1

DATA COLLECTION GUIDING QUESTIONS

	1. **Smallholder farmers**	2. **Focus group discussions**	3. **Organisations**
A. General questions on the perceptions of climate change and vulnerability to heavy rainfalls	• Have you been affected (directly or indirectly) by hazards caused by heavy rains? ✓ *If yes, which hazards did you face?* ✓ *Which damages did it cause to your farming (crops, livestock, infrastructure, transportation of goods, etc.?)* • How often did it happen in the last 10 - 20 years?	**(Similar to A.1 questions, but focusing on the impacts of heavy rainfalls on the farming as a group)** Example: impacts of agricultural cooperatives' farms	• What is your organization's mandate? • How does it work with farmers on climate change related issues in general, and on reducing smallholder farmers' vulnerability to heavy rainfalls in particular? • From your experience, are farmers aware of the climate change dilemma?

(causes & impacts of heavy rainfalls, floods, landslides on rural smallholder farming)	✓ *Is it regressive or progressive?* • What do you think are the causes of current intense heavy rainfalls?		
B. Access to and use of weather forecast and early warning information in farming decision making	• Do you have access to weather forecast and/or early warning information? ✓ *If yes, which type of information do you get? From who?* • How is the information provided to you? Though which dissemination channels? *(Radio, SMS, TV, meetings/workshops, Umuganda, etc.)* • Do you use the information provided, in taking decisions about your farming to reduce the impact of heavy rainfalls? ✓ *If yes, please give us more details*	**(Similar to B.1 questions, but focusing on the impacts of heavy rainfalls on the farming as a group)** *<u>Specific questions would include:</u>* • How is the information disseminated internally between farmers?	• Which services / products do you provide to farmers with regards to rainfall predictability / disaster management? • How is the provision of services / products done? • What does the institution think of the quality of services/products delivered? • How do you deliver the information to farmers? ✓ *Which communication tools do you use?*
	(Base on A1 answers) +		

C. Vulnerability and Climate Resilience	• When a disaster caused by a heavy rainfall happens, what do you do to cope with the impacts? • What do you do to improve the preparedness for future hazards?	**(Similar to C.1 questions, but focusing on the impacts of heavy rainfalls on the farming as a group)**	• What are the factors increasing smallholder farmers' vulnerability to heavy rainfalls? ***(here, they might indicate factors linked with topographic, demographic and/or socio-economic conditions)*** • What does your institution think of smallholder farmers' capabilities in coping with the impacts and improving preparedness to future hazards?
D. Satisfaction, Trust and Reliability in the information provided	1. Overall, are you satisfied with the quality of information provided by key institutions? 2. Do you rely more on the provided information or you prefer using your indigenous knowledge about weather forecasting and disaster management (if any)?	**(Similar to D.1 questions, but focusing on the impacts of heavy rainfalls on the farming as a group)**	• What does your institution think of the farmers' satisfaction of your services/products? • When designing certain services / products, does the institution take into consideration both the end users' knowledge and the local settings? *(indigenous knowledge or specific topographic of a certain region)*

E. Needs	1. What would you like to change in the type of information provided and/or its delivering systems? 2. Which type of weather forecast / early warning information do you need the most? (Seasonal, short term, long term, more localized, etc.) ✓ Assess their responses basing on ***accuracy, timing and localization indicators*** 3. Why do you need it? / What difference does it make in reducing the vulnerability?	**(Similar to E.1 questions, but focusing on the impacts of heavy rainfalls on the farming as a group)**	• Does your institution feel a need of improving quality in the design, provision and delivery of the weather forecast / early warning information? What would like to change in providing more accurate, timely and localized information?
F. Real scenarios / Successful stories	• Could you please describe to us one or two cases when you had used weather forecast information or the early warning information to prepare yourself to floods and/or landslides?	A description of past scenarios, where a community-based resilient farming / disaster management project was done, relying on the weather forecast information / early warning information	• Descriptions of projects / initiatives carried out by institution