Using agrometeorological data to equip local farmers for sustainable food production in Swayimane, KwaZulu-Natal

Adesegun Quam Popoola

Submitted in fulfilment of the requirements of

MASTER OF SCIENCE
in Agriculture
Agrometeorology Discipline
School of Agricultural, Earth and Environmental Sciences
College of Agriculture, Engineering and Science
University of KwaZulu-Natal
Pietermaritzburg
South Africa.

November 2019

PREFACE

The research contained in this dissertation was completed by the candidate while based in the discipline of Agrometeorology, School of Agricultural, Earth and Environmental Sciences of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa. The research was financially supported by Adaptation Funds in conjunction with uMgungundlovu District Municipality, South African National Biodiversity Institute and the University of KwaZulu-Natal under the auspice of uMngeni Resilience Project.

The contents of this work have not been submitted in any form to another university and except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.

Signed: Professor M.J. Savage

Date: 2 December 2019

DECLARATION ON PLAGIARISM

I, Adesegun Quam Popoola declare that:

1. The research reported in this dissertation, except where otherwise indicated or acknowledged, is my original work;
2. This dissertation has not been submitted in full or in part for any degree or examination to any other university;
3. This dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons;
4. This dissertation does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:
    a. Their words have been re-written, but the general information attributed to them has been referenced;
    b. Where their exact words have been used, their writing has been placed inside quotation marks, and referenced;
5. Where I have used material for which publications followed, I have indicated in detail my role in the work;
6. This dissertation is primarily a collection of material, prepared by myself, published as journal articles, books or presented at conferences. Where additional material has been included, I have indicated appropriately;
7. This dissertation does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation and in the references sections

Signed: Adesegun Quam Popoola

Date: 2 December 2019

ACKNOWLEDGEMENTS

I would like to thank the following people for their contribution and support:

First, to God Almighty, for the knowledge, wisdom and understanding you bestowed on me. The guidance and protection you provided during the course the course of this study.

My supervisor, Professor Michael J. Savage for the supervision and direction you have provided towards my research. You have been a source of inspiration. Your immense support is countless.

My co-supervisor, Dr Tafadzwa Mabhaudhi for your support.

I would like to thank the Principal and all the staff at Swayimane High School and Swayimane community for allowing the installation of the automatic weather station used in this project.

I would like to thank Mrs Meryl A. Savage, Dr Alistair D. Clulow and Mr Vivek Naiken for the administration, support and motivation towards this research.

My appreciation also goes to the South African National Biodiversity Institute, uMgungundlovu District Municipality, Janavi Da Silva, Mrs Neo Ntshobane, Dr Sibusiso Manzini of Greenmatter.

I would also like to thank Dr Sokfa John, Mrs Hirut Getachew, Miss Evidence Mazhawu, Miss Zibuyile Dlamini, Mr Jonathan Pasi and Dr Sheldon Strydom for their assistance, support and inputs.

Lastly, I would like to also say a big thank you to my wife, Mrs Snenduduzo Popoola, my two beautiful daughters, Simi and Timi, my mother Mrs Morufat Popoola, my siblings, Ayodele, Bukonla, Bola and Tokunbo, my late mother-in-law, Mrs Emelda Zondi, my friends, Dr Adeolu, Temi, Chris, and Abulele.

ABSTRACT

Agriculture is largely dependent on climate and weather conditions and changes, and consequently, sustainable food production especially in Africa where it is overdependent on rain-fed agriculture. Evidence abounds of climate change and its impacts all over the world, and how this threatens agriculture and food sustainability as many rural farmers are often more vulnerable to the direct impacts of adverse weather and climate variation. Thus, agrometeorological information and services have become indispensable for mitigating such adverse effects and for sustainable food production. To achieve its objectives of reducing the vulnerability of rural communities and small-scale farmers to climate change in the UMDM through increased climate resilience, the uMngeni Resilience Project (URP) in collaboration with UKZN aims to provide farmers with access to weather forecasts, particularly, South African Weather Service (SAWS) and eNCA information. An AWS was installed at Swayimane High School, as a way of achieving this intervention.

This study sought to understand the effectiveness of the weather information provided to farmers in Swayimane, the methods of dissemination and the farmers' own assessment of such information and the methods used to inform them. The study utilized a qualitative approach involving information meetings and interaction with farmers, as well as interviews. Among other things, the study found that poor crop yields and livestock were the primary weather variability-related challenges farmers experienced in Swayimane as their agricultural activities did not always produce the desired or expected outputs. Increased access to agrometeorological information also increased the chances of better decision-making among farmers and potentially, better outputs. The general assessment of the information sessions and the dialogical group method of disseminating weather information to farmers was positive, and the farmers expressed a desire for continuous and consistent access to weather information in ways they can interpret on their own. The study recommended closer and more regular interaction with farmers in the community, and the implementation of methods that allow farmers more direct access to weather information in an interactive manner, and if possible, in their local language.

Table of Contents

LIST OF ACRONYMS

AIM	Agrometeorological Instrumentation Mask
ALP	Adaptation Learning Programme
ASSAR	Adaptation at Scale in Semi-Arid Regions
AU	African Union
AWS	Automatic Weather Station
DEA	Department of Environmental Affairs
FAO	Food and Agriculture Organisation
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GIEWS	Global Information and Early Warning System
GIS	Geographical Information Systems
ICTs	Information Communication Technologies
IPCC	International Panel on Climate Change
IVR	Interactive Voice Response
KBS	Knowledge-Based System
KI	Key Informant
NIM	National Institute of Meteorology
NGOs	Non-Governmental Organisations
NOAA	National Oceanic and Atmospheric Administration
RTMC	Real-Time Monitor and Control Software
SADC	Southern African Development Community
SAWS	South Africa Weather Service
SCF	Seasonal Climate Forecast
SMS	Short Messaging Service
UKZN	University of Kwazulu-Natal
UMDM	Umgugundlovu District Municipality
URP	Umngeni Resilience Project
USAID	United States Agency for International Development
WMO	World Meteorological Organization

LIST OF FIGURES

LIST OF TABLES

Chapter 1: INTRODUCTION

1.1 Background and rationale for the study

The World Meteorological Organization (WMO) observes that agriculture is likely the most weather- and climate-dependent of all human activities regardless of the impressive agrotechnological advancements of recent years (WMO, 2012). Thus, the failures and/or successes of agriculture (and consequently, sustainable food production) are largely determined by weather and climate conditions and changes (Werford, Moran & Adger, 2010). Evidence abounds of climate change and its impacts all over the world, and how this threatens agriculture and sustainability of food production. For example, 2016 was reported to be the hottest year on record since global air temperature records began in 1880 (Northon, 2017). The global average air temperature in 2016 was 0.99 °C above the 20th century average. It is therefore the third year in a row to set a new record on global average air temperature (Northon, 2017). This warming of the world's climate is the result of the build-up of greenhouse gases in the atmosphere, especially in the last century. Thus, in the last two decades, there has been an increased frequency of events such as high surface air temperatures, floods and droughts. While these extreme events are accounted for by climate variability, they are also an indication of the long-term changes in near surface temperature and rainfall patterns.

The agricultural production system at large is affected by weather and climate variations in terms of the suitability of specific lands for different types of crops and pastures, and incidences of pests and diseases which affect biodiversity, livestock, fisheries and the environmental health of food systems. This is because crop yield is the combination of different climatic factors that either directly or indirectly affect agricultural productivity (Werford *et al.,* 2010). For example, rising surface temperatures and changes in rainfall patterns directly affect agricultural productivity, and changes in the availability of water for irrigation indirectly impact on productivity. Increased air temperatures result in wilting of crops because of increased transpiration. Changes in the air temperature, solar radiation, and precipitation also affect crop and livestock production. Winter air temperatures are especially important for the survival of pests, and studies have shown that increases in air temperature accelerate the development of pests in general (Easterling *et al.,* 2007; Tshiala *et al.,* 2011; Werford *et al.,* 2010). Many of the world's subsistence farmers, especially rural people, who depend on agriculture for sustenance and livelihood, are often more vulnerable to the direct impacts of adverse weather and climate variation than commercial farmers who can utilise artificial farming methods (Molnar, 2010). Pest-crop interaction is also affected by rising CO_2 concentration levels through the alteration of host plant attributes. In particular, CO_2-temperature and CO_2–precipitation interactions are recognised as the key factors in determining the intensity of damage from pests (Easterling *et al.,* 2007). In terms of climatic elements, carbon dioxide concentration, air temperature, solar radiation, precipitation and atmospheric humidity in particular affect agricultural food production. Due to its overdependence on rain-fed agriculture, Africa is highly vulnerable to the effects of climate and weather changes, especially the climate-dependent livelihoods of small-holder farmers (Nhemachena & Hassan, 2007). This is an additional challenge which tends to intensify already daunting agricultural problems farmers grapple with and increases the threat to food production and livelihoods (Morton, 2007).

Signs of such warming and increased rate of rainfall extremes are observed in Africa, and more relevant to the present study, in South Africa, where a rapid increase in maximum air temperature is recorded (Tshiala, Olwoch & Engelbrecht, 2011). Also rapidly increasing is the intensity of daily rainfall and the duration of dry spells which were demonstrated to be statistically important in Southern Africa (Department of Environmental Affairs (DEA), 2013). Changes in air temperature in Southern Africa have been linked to higher risk of ruinous wildfires, and other forms of disaster (Werford *et al.,* 2010). This is a threat to several South African communities, especially rural and poor households, who are less equipped to adapt to these changes. Some such communities have suffered loss of lives and property in recent years due to damaging extreme climatic events (DEA, 2013).

South Africa, which is the second largest economy in Africa, has adequate food supply at the national level, however, this is not the case when food security is measured at the household level (Tibesigwa & Visser, 2015; Tibesigwa *et al.,* 2015). Recent statistics show that at least 45.6% of South Africans are food secure, 28.3% are at risk of hunger, and 26% are food insecure (Tibesigwa & Visser, 2015). This situation is likely to worsen given a projected increase in climatic variations, its effect on weather patterns and, consequently, food production. It should be noted, however, that such effects are not isolated from other aspects of life. South Africans, especially rural dwellers, who suffer more from poor crop yield and food production, have a higher likelihood of being exposed to other challenges such as unemployment, poverty, starvation and sometimes death. These are issues that cannot be treated in isolation from climate change and its resultant effects on food security.

While massive, collective and long-term strategies are required to manage and, perhaps reduce the impact of climate change and related weather vagaries, much can also be done in the short-term to ensure continuous and sustainable agriculture, especially among communities that depend mostly on farming, such as Swayimane, in the uMgungundlovu District Municipality (UMDM). This requires an investment in understanding climate change and the numerous ways it affects small-holder farmers, as well as the sensitivity of local agriculture to climatic and weather conditions so as to develop appropriate systems and strategies that can ensure sustainability of the agroecosystem and food production (Ndlovu, 2019).

It is in view of this that agrometeorological information and services have become indispensable for sustainable food production. Thus, to achieve its objectives of reducing the vulnerability of rural communities and small-scale farmers to climate change in the UMDM through increased climate resilience, the URP, championed by the UMDM, aims to provide farmers with access to weather forecasting, particularly, South Africa Weather Service (SAWS) and eNews Channel Africa (eNCA) information. The project seeks to increase resilience and reduce vulnerability of local communities within the UMDM through the use of integrated traditional and scientific knowledge in adaptation. This includes interventions such as (i) early warning and disaster response systems; (ii) ecological and engineering solutions targeted on infrastructure for vulnerable communities; (iii) integrating climate-resilient crops with climate-smart techniques; and (iv) disseminating lessons learnt on adaptation (UMDM, n.d.)[1]. So far, the project has commenced within four distinct sites that were selected through a vulnerability assessment. These sites include low-lying high-density areas as well as rural areas in Ward 8 of Msunduzi, uMshwathi, Ward 8 of Vulindlela and Richmond Local Municipalities.

[1] http://www.umdm.gov.za/Official_Site/index.php/municipal-services/climate-change/umgeni-resilience

As part of the URP project, and in light of the challenges of climate change and vulnerability of Africa, this research project provided Swayimane farmers with short-term (and seasonal) weather information such as air temperature, rainfall and the effects they were expected to have on agriculture and food production. This is to equip the farmers to better manage and be resilient to the adverse effects of climate and weather variability. Since the URP intervention is on-going and systems need to be tested, evaluated and improved for better output, the study focused on examining the kind of agrometeorological information provided to the farmers, the system of dissemination, the receptivity and interaction of farmers with the information provided to them and whether they found these to make a difference in their farming practices and attitudes. This will offer opportunities for integration of more scientific and traditional strategies to equip small-holder farmers in Swayimane for more sustainable food production despite persistent climate change.

1.2 Significance of the study

Developing countries such as South Africa suffer more from the severe effects of climate change due to their limited adaptive capacity (Ababale, 2013). Climate projections indicate that the (UMDM) in KwaZulu-Natal will experience a warmer future with uncertain changes in mean annual rainfall, an increased number of flash flood and storm events due to an increase in short duration rainfall (CNA Military Advisory Board, 2014). With floods, severe storms and wildfires being some of the main hazards already currently faced by communities in the UMDM, the projections are of grave concern as they indicate an increased risk of these climate-driven events, including potential increase in drought events. This study will aid to reduce the vulnerability of small-scale farmers in Swayimane community to the impacts of such extreme events. The study suggests a direction for responding to climate change risks and challenges, especially as manifested in changes in weather patterns.

The collation and dissemination of agrometeorological information to local farmers is important in conservation and management of natural and environmental resources for sustainable food production. The sharing and discussing agrometeorological information with farmers in Swayimane could enable them to cope more efficiently with weather, and ultimately, climate variability and minimize losses in agricultural production. The information will equip farmers to make better choices about which crops to produce and manage more efficiently at a given time or during a specific season. It will also help them to more efficiently manage assets such as land, labour, fertilizer, and how ascertain much of their resources will be devoted to each crop.

The study will also add to the existing body of knowledge on the impacts of climate change in poor communities and the possible mitigation techniques. With existing theoretical knowledge showing that climate change has been contributing negatively to agricultural outputs across the world, this study will contribute to literature through investigating the impact of climate data on farmers' resilience to climate change.

1.3 Nature and scope of the study

The study was conducted in Swayimane, a rural community in uMshwathi Municipality, KwaZulu-Natal. The satellite coordinates of the location are latitude 29°25'50"S and longitude 30°34'32"E. Swayimane has an area of 36.35 km^2. In addition, the elevation of Swayimane is between 800-1000 m and has a gentle terrain (Matungul, 2000). Swayimane has an area of 36.35 km^2 . This research was part of the URP "Building resilience in the greater uMngeni Catchment, KwaZulu-Natal, South Africa". It aims to increase resilience of vulnerable communities through interventions such as early warning systems, climate-smart agriculture and climate proofing settlements. The project involves the installation of an Automatic Weather Station (AWS) located at Swayimane High School in Ward 8 of Swayimane community (Figure 1.1) to collect agrometeorological data to help the community to understand, plan and respond to weather events, and in particular, adverse weather.

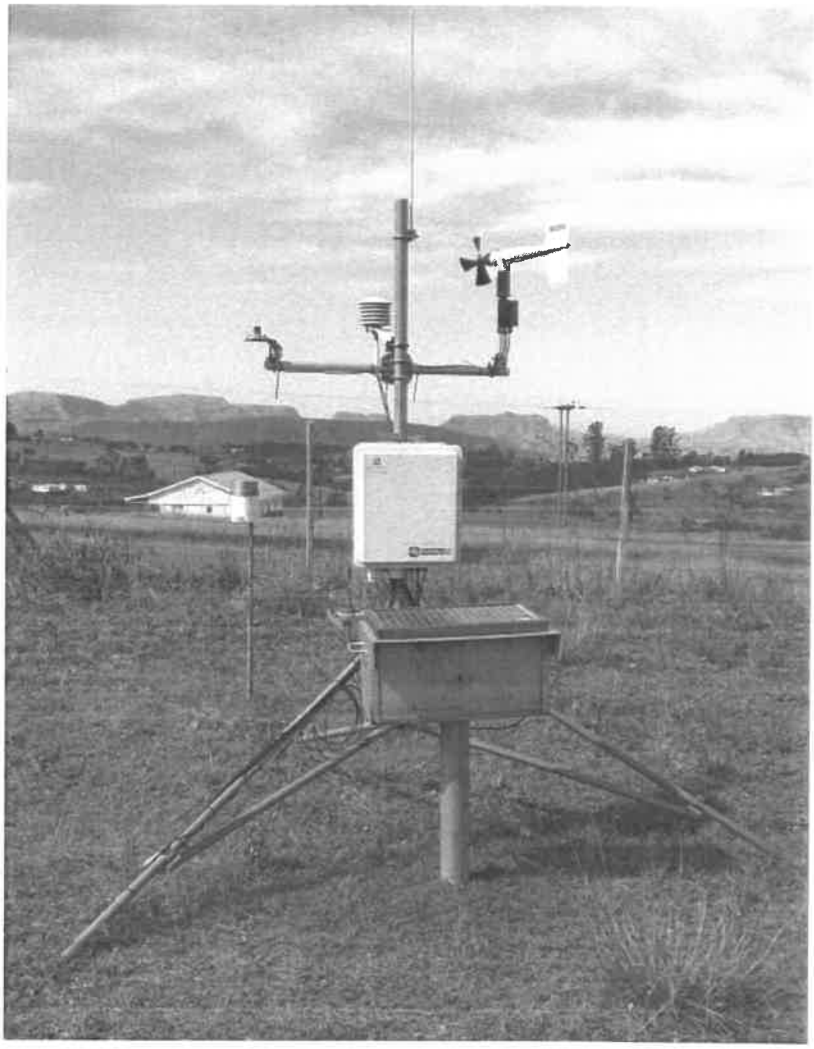

Figure 1.1: AWS system in Swayimane High School

This AWS is equipped with different sensors which measures several meteorological parameters such as solar radiation, relative humidity, wind speed, wind direction, rainfall patterns, air temperature, soil temperature, soil water content and leaf wetness duration. This provides agro-climatic information useful to local farmers to adjust their farming activities in line with varying weather conditions to achieve sustainable food production, and to achieve a more productive and sustainable use of land, water, and renewable natural and environmental resources. It enables the measurement of rainfall patterns which guide irrigation, drainage and agricultural planning, flood and drought preparedness. It guides on average sowing dates as well as expected sowing dates, environmental risks and disaster mitigation measures, highland and mountain agriculture, information on weather related pesticides/insecticides applications based on low level winds for operational purposes. A mobile system (currently being developed) was used to disseminate relevant weather information to farmers. Dissemination of weather information was complemented with personal contact and interaction with farmers in order to provide clarity and further guidance where necessary, and to observe farmers' reception of and interaction with the information provided to them.

1.4 Aim of the study

Overall, this study aimed to understand how weather information collected through the AWS and disseminated through the Agrometeorological Instrumentation Mast (AIM) web-based system and on-screen at Swayimane High School enhances resilience of the formers to climate change and increase sustainable food production. The study particularly evaluates the effectiveness of the weather information provided to these farmers, the ways it was disseminated and how farmers made use of such information. The larger project is located in the school in the hope that students will learn about the AIM data and develop sufficient knowledge to communicate and translate such data to their families and the wider community. Thus, the data is displayed in a visual manner that is readable to a layperson.

1.5 Research question and objectives

1.5.1 Main objective

To assess whether access to AIM data enhance effective agricultural decisions among farmers in Swayimane and increase their sustainable food production and resilience to variability caused by climate change.

1.5.2 Specific objectives

1. To collate and disseminate AIM system's weather information to farmers in Swayimane
2. To understand the weather information received by farmers and its implications on their farming decisions and practices.

1.6 Structure of dissertation

The dissertation is organized into six chapters. Chapter 1 introduces the study, outlining the climatic variability challenges faced by communities such as Swayimane as well as the significance, scope and outline objectives of the study. Chapter 2 locates the study in the broader academic and scientific context by reviewing relevant previous literature on the topic. The research methodology and other significant information about the study area is discussed in Chapter 3. Chapter 4 presents an analysis of the results of the study, including the different meteorological components collected using the AWS located in the study site and farmers' experience of the information resource system. In Chapter 5 the results are discussed, and Chapter 6 offers conclusions and makes recommendations based on the findings of the study.

Chapter 2: LITERATURE REVIEW

2.1 Introduction

This chapter offers a thematic review of relevant literature on the use of agrometeorological information and technologies to address issues related to sustainable food production and security in view of climate change. To offer a broader context, literature on climate change and variability is examined in this chapter. The impact of climate change on agriculture is discussed, suggested mitigation strategies that farmers have been observed to adopt. The chapter further explores literature on the use of agrometeorology as a key mitigation strategy and method for ensuring sustainable agriculture. The crucial issue of methods and technologies for managing, disseminating and communicating agrometeorological information to small-scale farmers in farming communities is discussed. Examples of previously implemented strategies are reviewed as well as the several challenges and limitations highlighted by scholars. Overall, the literature shows that several advances have been made in Africa and beyond in developing effective technologies, knowledge-base and systems for understanding and managing climate change and vulnerability. However, developing countries are still faced with immense challenges and small-scale farmers in rural areas are still largely unable to benefit from existing models of processing and communicating agrometeorological information in ways that are timely, meaningful and useful to farmers to effectively inform their agricultural decisions. The reviewed literature, therefore, offers on the one hand, a critical research basis for the present study on the use of agrometeorological data for sustainable food production in Swayimane. On the other hand, the literature highlights the significance and relevance of the present study to further inform the field based on interaction with small-scale rural farmers.

2.2 Climate change, variability and agriculture

Reports show that global temperatures have consistently risen with each year, from 2014, becoming hotter than the preceding year. Steffen and Fenwick (2016), in their report, *The Hottest Year on Record (Again),* discuss the emergence of 2015 as the hottest year ever recorded globally since the beginning of global recording of air temperature in 1880. Air temperature, in 2015, rose by 0.9°C compared to the 20th century, and by 0.16°C compared to the previous hottest year, 2014

(National Oceanic and Atmospheric Administration (NOAA), 2015). However, the United States NOAA (2017) reported in its most recent annual state of the climate report that 2016 is officially the hottest year in recorded history, surpassing the 20th century records by 0.90 °C. The report further explained that 2016 had the highest global average concentration of CO_2, which was 402.9 μL L^{-1}. This indicates that 2016 had the highest concentration of greenhouse gas on record and was the first in more than 800 000 years in which CO_2 levels went beyond 400 μL L^{-1}. Furthermore, in 2016, sea level, sea surface temperature, and lower atmospheric temperature all reached their highest global averages, and the extent of the Antarctic sea-ice dropped to the lowest ever recorded.

Steffen and Fenwick (2016) however, suggest that air temperature will have been on the rise for 39 consecutive years by 2019, when compared to temperature in pre-industrial times, because the average of the 20th century temperatures indicates strong warming since 1970. Thus, they note that considerable variability is also observed during this period, but the trend of increasing warming is clear and consistent especially from the middle of the 20th century. In other words, the 2000s were warmer than the 1990s, and the latter warmer than the 1980s, and these three decades were warmer than the decades from 1850. This is, perhaps, one of the strongest indications of climate change. Steffen and Fenwick (2016) observed that the burning of fossil fuels, including oil, gas, and coal, is the primary cause of the increase in greenhouse gasses (CH_4, CO_2 and N_2O) in the atmosphere, which fuels climate change. It is observed, for example, that carbon dioxide emission between 1970 and 2010 alone equalled the emission of carbon dioxide in the centuries between 1750 and 1970, and there has been an increase in the rates of emission from 1.3% per year from 1970 to 2000, to 2.2% from 2000 to 2010 (International Panel on Climate Change (IPCC), 2014). Thus, due to the increase in the concentration of greenhouse gases in the atmosphere, the world is bound to experience hotter climatic conditions.

While these authors focus on the human activities that contribute to climate change, Khan *et al.* (2009) highlight the fact that the climate, since the advent of evolution about 5 billion years ago, experiences a self-paced change. Thus, the present concerns with climate change do not seek to present climate change as entirely the result of human activities, but that anthropogenic interference and disturbances have increased the momentum of such change. This has produced adverse effects on human life by affecting the biosphere and human health which are already visible in the interactions between human beings, microbes and the entire biosphere. This is evident in changes in rainfall patterns, ice-melting, increases in sea levels and several other indicators which demand urgent attention to forestall the adverse effect of such change and to enable human beings and systems to adapt as they increasingly become vulnerable to these changes in several ways.

Khan *et al.* (2009) describe vulnerability, in the context of climate change, as susceptibility or the extent to which systems are not able to cope with the adverse impacts of climate change as well as extreme climatic conditions and variability. Thus, this has to do with the amount and rate of climate variation and change to which a system is exposed and the system's sensitivity and capacity to adapt to such change. This is because different geographical locations, people, societies, sectors and spheres of life are affected differently by climate change and have different adaptive capacity and sensitivity. Thus, Khan *et al.* (2009) argue that understanding vulnerability at a local and regional level is important to any kind of intervention. However, they also argue that the impact of climate change anywhere is not experienced in isolation from other stresses, such as globalization and the social and economic changes it engenders which also creates new risks and possibilities.

While climate change is a global phenomenon, and every part of the earth is affected directly or indirectly, Africa and other developing countries are viewed as suffering the most, and more likely to remain the most affected by the impact of climate change. Amegnaglo (2015) observed that while it can be said with certainty that climate change has a significant impact in Africa, the future patterns in Africa are generally not clear. The author observes two attitudes from analysts of climate change in Africa. The first is pessimistic and observed among scholars such as Mendelsohn *et al.* (2000), Nelson *et al.* (2009) as well as Schlencker and Lobell (2010). The pessimistic attitude holds that air temperatures, relative humidity, greenhouse gas concentrations, and solar radiation will increase and there will be a decrease in rainfall which will significantly damage the agricultural sector. The second is optimistic (Adejuwon, 2006; Liu *et al.* 2008). These scholars, contrary to the pessimists, believe that rainfall will not decrease across Africa, but that some parts will experience an increase in rainfall and the increase in the concentration of carbon dioxide together with such rainfall increases could result in improved crop yield. They do not, however, dispute the observation that air temperatures will continue to rise, and Schlenker and Lobell (2010) suggest that the increase in rainfall will not match the air temperature increase. Thus, the increase in air temperature predicted by the optimist may not necessarily compensate for the associated damages.

Amegnaglo (2015) further observes that increase in the concentration levels of greenhouse gases will affect precipitation, solar radiation, relative humidity and temperature. They draw on the 2007 report of the United Nations IPCC that Africa as a continent will experience increase in average air temperature that will be 1.5 times greater than the global average by 2090 to 2099. Thus, evaporation, relative humidity and crop transpiration will increase resulting in the proliferation of pests and weeds as well as low crop yield. Changes in seasonal trends, droughts, floods and other extreme events are also expected. The IPCC's Fifth Assessment Report of 2013 has further confirmed these observations about climate change and its impact globally and in Africa, and together with other reports, increasingly point to more warming and more changes as a result. Thus, climate change and its adverse effects are highly established. This foundational literature on the nature, causes, extent, rate and impact of climate change and variability offer useful background to climate change and a useful basis for this study which seeks to explore agrometeorological data for sustainable agriculture in the Swayimane community. More relevant, however, is a thorough understanding of the impact of climate change on agriculture specifically.

2.2.1 Effect of climate change on agriculture and sustainable food production

Nelson *et al.* (2009), in their examination of the cost of adaption of vulnerable systems and people to climate change, offer key insights. They observe that almost 2.5 billion people in developing countries, who are economically active, depended on agriculture as a source of livelihood in 2005 alone. As at 2009, 75% of the global poor are located in rural environments and rely on agriculture to some extent. According to Myers, Smith, Guth, Golden, Vaitla, Mueller, Dangour, and Huybers (2017), climate change is set to increasingly make life more difficult for vulnerable populations because of the ways it will affect yield of crops that are most valued. Nelson *et al.* (2009) also observe that in South Asia, irrigated yields of many different of crops will be affected immensely. This will result in increases to prices of agricultural crops considered most important, such as rice, maize, soybeans and wheat. This will have consequences for meat prices because the prices of animal feed will be affected. Thus, they believe that climate change will ultimately stall the rise in consumption of meat and affect substantially the consumption of cereals. Furthermore, the amount of food calories available by 2050 will decline immensely which will lead to malnutrition in children. Thus, the milestones that could have been achieved by 2050 in terms of addressing the problems of malnourishment in children, if there were no climate change, would be eliminated by climate change (Myers *et al.*, 2017).

Nelson *et al.* (2009) further observe that the prices of the most important crops are set to rise with or without climate change, but climate change will accentuate this increase. For example, the prices of rice, maize, wheat and soybeans between 2000 and 2020 will only increase by 62%, 39%, 63% and 72% respectively due to growth in income and population as well as demands for biofuels, even without climate change. However, climate change will bring about additional increases in prices by 32-37%, 52-55%, 94-111% and 11-14% respectively. While livestock from the perspective of Nelson *et al.* (2009) are not affected directly by climate change, the price increase in animal products such as beef will significantly increase by 2050 due to the effect of climate change on feed. Nelson *et al.* (2009) expose further the impact of climate change directly on agriculture and indirectly on livestock, consumption and the economy. They further highlight the underlying importance of agriculture to human survival, and thereby, the extent to which climate change poses a challenge to food production and sustainability.

While studies such as Maponya and Mpandeli (2012) emphasize cost and economic factors in their examination of the effect of climate change on agriculture, Iheke and Agodike (2016) emphasize agricultural and biological factors. In their study, Iheke and Agodike (2016) highlight the fact that climate change affects the support system of biophysical life such as vegetation and land surface, soil, atmosphere and water resources. These systems are responsible for the sustenance of life on the planet; thus, food security and production are highly threatened by the projections about precipitation, air temperature rise and other consequences of climate change. The authors further observe that both agriculture and the institutional and social institutions and structures that support them are affected by climate change. Thus, while climate change affects crops and livestock, land, soil, water, pest proliferation, sea levels, salinity, sea temperature and fish, it also affects GDP that is based on agriculture, prices in the world market, trade and distribution of trade regimes geographically, global hunger risks and food security, conflicts and social unrest, migration and governance. Moreover, those most vulnerable are children, the poor and elderly people. These challenges are more pronounced in Africa because it is most vulnerable to the impact of climate change globally (Iheke & Agodike 2016). This is already manifesting in rainfall patterns, dryness, disease incidences, loss of fertility in soil, soil erosion and floods, strong winds, some species of crops becoming extinct, overflowing streams and rivers, loss of forests, and erratic patterns of rainfall, among other things. These observations support the model by Khan *et al.* (2009), which seeks to offer a more comprehensive view of the effect of climate change on agriculture (Figure 2.1).

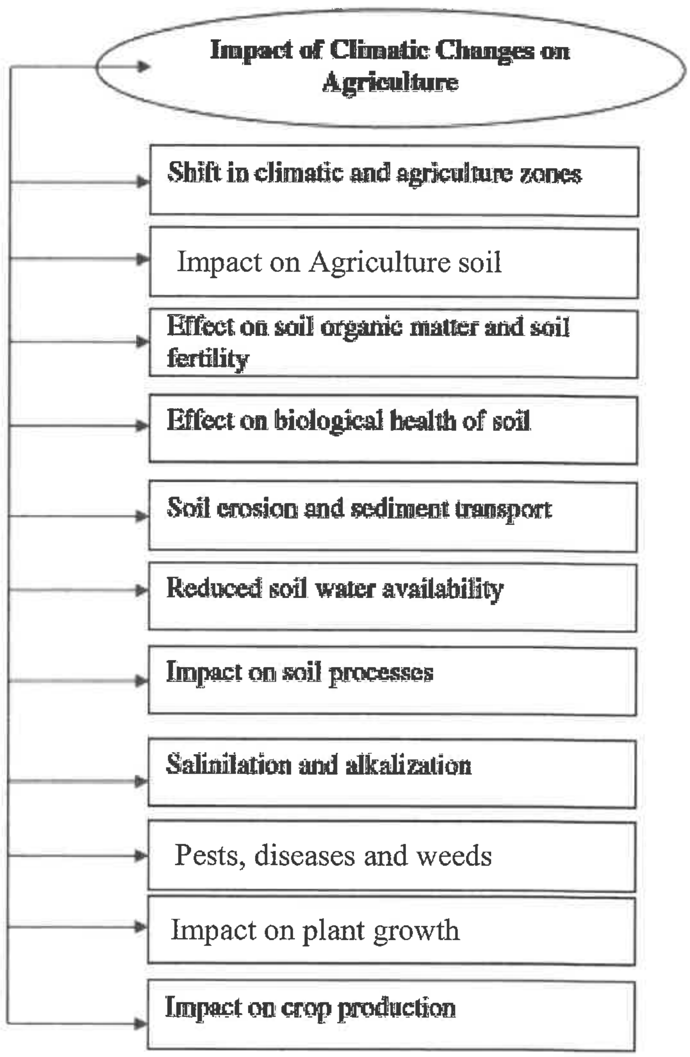

Figure 2.1: Impact of climatic changes on Agriculture

Source: Khan *et al.* (2009)

The authors argue that to fully understand and discuss the impact of climate change on agriculture, the points listed in Figure 2.1 must be taken into consideration. These include shifts in agricultural and climatic zones, impact on soil, fertility and soil organic matter, pests, diseases and weeds, crop population, salinity and alkalinity, soil water, soil erosion and biological health of the soil, among other things. Selvaraju *et al.* (2011) emphasize the variation, in terms of region, in the effect of climate variability and change, as well as vulnerability. They point out that one-fifth of the continental areas of earth are mountain regions and are dominated by cultural minorities. Thus, these groups are more likely to suffer from the adverse impact of climate change because such regions have ecosystems that are very sensitive. Moreover, because they are sloping lands, the negative impact of heavy downpours and storms is greater as they produce avalanches, floods and landslides. Additionally, groups in these mountain regions depend heavily on agriculture and livestock and thus, are at a high risk.

The effect of climate change on agriculture is more daunting because agriculture has a substantial connection to weather and climate. Selvaraju *et al.* (2011) note that these are the key factors in the question of variability in the production of food. The impact of climate change, they observe, is already threatening the goal of increasing the production of food by 70% by 2050 to match the projected increase in global population to 9.1 billion by the same year. This is compounded by the fact that, as noted by Amegnaglo (2015), agriculture is an underperforming sector in Africa and is unable to attain its output and yield potential. Agricultural yields, the authors observe, have actually decreased compared to the 1960s partly because of the low reception by farmers, the availability and adoption of new agrotechnology and innovations as well as partly due to climate change. However, climate change remains the major factor in the variability of yields and is beyond the control of the farmer or policymaker. Moreover, the authors agree that Africa is more likely to suffer severe consequences of climate change on agriculture due to the dependence of agriculture in the region on climate, as well as poor institutions to support agriculture, unfriendly working environments for farmers and meagre incomes with which farmers are rewarded.

Unlike several other authors, including the ones discussed so far, who tend to emphasize more of the adverse effects of climate change on agriculture in Africa, Khan *et al.* (2009) highlight both adverse and potentially positive effects of the phenomenon on agriculture and food production. They note, for instance, that the concentration of carbon dioxide in the atmosphere could enhance crop fertilization for crops with C3 photosynthetic pathway. This could increase the productivity and growth of crops. However, they also note that the downside could be a reduction in the duration of crop, increased respiration, support of survival and spread of pests, increased soil mineralization and increase in evaporation, among other things. Additionally, the authors note that while climate change could catalyse organic matter decomposition to release nutrients within a short time, it could also lead to low fertility in the long term.

2.2.2 Mitigating the impact of climate in Africa

Given the nature of current and projected impacts of climate change globally and in Africa, mitigation and adaptability strategies are a growing concern among stakeholders and agricultural research. A major and promising mitigation strategy that has been widely explored in relation to agriculture, is the adoption and application of innovations in agrotechnology. This could include technologies for harvesting rainwater, irrigation, fertilizers, mechanization, insecticides and pesticides, varieties of new crops that can withstand the changing climatic conditions, as well as obtaining meteorological information (Okezie *et al.,* 2011; Selvaraju *et al.* (2011) highlight the inability of many farmers in Africa to adopt and use these innovations primarily due to financial limitations and lack of institutional support. Roncoli *et al.* (2002) suggest that these are not (the only) primary factors as cultural factors also heavily affect farmers' attitude towards the adoption of new technologies. They argue that already internalized cultural worldviews, modes and desires play a major role in how people receive scientific knowledge and innovations. Thus, several African farmers, and farmers elsewhere, rely on their indigenous knowledge and explanatory systems which have guided them in the past to predict weather and climate conditions and patterns, and to help them in making important agricultural decisions. Yet in their study, Selvaraju *et al.* (2011) observed that while farmers depend on these indigenous knowledge and tools, they are aware of the limitations of such methods and they recognize that their approaches are not accurate. Roncoli *et al.* (2001) note that climate change and variability increasingly make such reliance on indigenous knowledge systems and methods problematic as new climatic patterns emerge. Selvanraju *et al.* (2011) further argue that the first step towards mitigation of the adverse effect of climate change on agriculture and that achieves sustainable food production is to understand the ways in which crops, farm animals and trees interact with natural resources such as land, soil, water and climate. They further note that scientists must learn to view climate as a resource. This will enable them to characterize agroclimatic resources and establish systems that are suitable for agriculture, socially acceptable and appropriate technologically. Kassie *et al.* (2013) also insist that a thorough assessment of the already available strategies and practices among farmers to mitigate the risks posed by climate change and variability is a necessary step towards the improvement and recommendation of new strategies. They argue that this is because farm households develop their own strategies, depending on their experiences and their own assessments of risks. This enables them to adapt to the social, economic and environmental changes they encounter.

The study conducted by Iheke and Agodike (2016), for example, shows several mitigation strategies that are already in use by farmers. Some of the most adapted strategies in Africa include the construction of drainage and flood barriers, multiple cropping, use of improved or enhanced crop varieties, mulching, altering planting dates, irrigation, prioritizing of cover crops and planting of trees. However, they observed that strategies such as planting of vetiver grass and agroforestry were least used by farmers. Rather, farmers protected the farms from crop failure due to climate change by adopting multiple cropping or controlled erosion through contour ploughing. Farmers also used zero or minimum tillage to manage the possibility of soil eroding during heavy rainfall, to improve the absorption of water, reduce the release organic matter and carbon trapped in soil, reduce the use of fossil fuels during ploughing and to maximize profit by saving on expenses due to ploughing and tilling. In Ethiopia, Kassie *et al.* (2013) observed that farmers' adoptive strategies also commonly included decisions about crop variety and types, cropping calendar adjustment, conservation of moisture. However, Kassie *et al.* (2013) also observed while these strategies and practices were relatively inexpensive to farmers, they were within the boundaries of the adaptive capacity of farmers and were not always sufficient for addressing the impact of climate change. They also may not be sufficient for future impacts as new kinds of risks are expected from projected climate changes which are beyond the range of farmers' current experiences and knowledge. Thus, they suggest that farmers need to be assisted to access important technologies, institutions and markets to enable them to prepare for increasing climate change driven risks. This is partly because when farmers' knowledge, perception and experiences do not match the observed and anticipated trends in climate, their strategies could become counterproductive (Maponya & Mpandeli, 2012). Thus, they need to be assisted through greater communication and building capacity by such institutions as climate field schools. Such strategies Kassie *et al.* (2013) recommend, should aim to address issues related to agricultural inputs, access to market, knowledge strengthening and information services, among other things.

2.3 Application of meteorology for sustainable agriculture

While weather forecasts are variously utilized today by various organizations, when systematic weather records began in the 17th century, it was primarily for agricultural purposes to assist farmers plan and make decisions. The adoption and use of meteorological technology such as AWS and information such as weather patterns and air temperature for agriculture sustainable agriculture have become indispensable to sustainable agriculture in the light of climatic change and variability. In their introduction to a guide on the practice of meteorology in agriculture, Stigter *et al.* (2013) identified the primary concern of agricultural meteorology/agrometeorology to be the pedological, hydrological, meteorological and biological facts that impact production in agriculture, as well as agriculture's interaction with the environment. Thus, it aims to assist farmers to prepare and be informed through supportive application of meteorological information, knowledge and services. Such information could include environmental resources available to farmers, interactions beneath the soil surface, interface of air and soil, and atmospheric boundary layer among other things. Moreover, despite agrotechnological advancements, agriculture remains heavily dependent on climate and weather, thus the relevance of agrometeorology. Stefanski *et al.* (2010) offer a detailed discussion on the usefulness and application of agrometeorology for sustainable farm management and food production, for maintaining crop health, resolving problems related to operations, increasing crop yield and the economic values of their crops. However, they argue that for any application of climate and weather information to be effective, there must be a solid data foundation, an efficient analysis and interpretation of such data, and that the users who apply the result of such analysis must be prioritized in the process. This could be the farmer, government official, extension worker, the general public or anyone involved in agricultural decision making.

Different methods have emerged and are currently used to draw on agrometeorological data to assist farmers Selvaraju *et al.* (2011). These have also been developed and applied in Africa since the 1980s to offer farmers information concerning atmospheric developments. This includes air temperature, wind, rainfall, cloudiness, the quality of air, expected weather and climate events such as storms, droughts, floods, cold and heat waves as well as the projected impact of such events. Such meteorological services are either focused on climate or weather services as determined by timescale. Such information is useful for long-term decisions regarding optimal crop type, farming system, type of farm equipment, pest control and irrigation. Weather forecasts, on the other hand, are usually for 10 days or less and assist with short term decisions and actions such as planting dates, plant spacing, density, alternative crop variety, timing of water and application of fertilizer, and other regular daily farming operations. The reasoning behind providing such meteorological information to farmers is that knowledge about near and distant future in terms of wind direction and speed, evaporation, precipitation, cloudiness, air and soil temperature, and relative humidity, will enable them to make better decisions concerning crop variety and type, labour, land, fertilizer, labour and finances (Asfaw *et al.,* 2014). It will also enable them to adopt appropriate and more effective technologies, invest in storage and production and make decisions that will assist them to minimise risks and losses that could be caused by weather conditions. This ultimately increases yield both in terms of quality and quantity (Asfaw *et al.*, 2014).

However, this process is still highly challenged in Africa for several reasons, including the high cost of providing meteorological services to farmers. Furthermore, studies reveal that late delivery of meteorological information to farmers is a major challenge as farmers are either unable to utilize such information or they ignore it. This is revealed by Ingram *et al.* (2002) whose study indicates that in order to make meaningful use of meteorological information, farmers need to receive it approximately two months before the relevant season. This is because a series of decisions needs to be made in due time before the season commences, such as optimal land, allocation of labour, choice of crops and other preparations. Thus, some meteorological information becomes irrelevant when disseminated to farmers after these decisions already have been made or when the rainy season has commenced. Thus, from an assessment of literature, and own statistical research, Amegnaglo (2015) discovered that the optimal period for advance dissemination of agrometeorological information to farmers is one to two months prior to the relevant season. Furthermore, for such information to be useful to farmers the level of accuracy needs to be 60% to 70% as information that is less than 60% accurate could negatively impact decision making.

Thus, the value of agrometeorological information depends on whether or not the farmers find them useful so that their decisions are informed by such information (Hansen, 2002).

However, farmers do not always make decisions based on information provided to them. In their study of the use of agrometeorological information in Namibia and Tanzania, for example, O'Brien *et al.* (2015) observed that many farmers (60% in Tanzania and 13% in Namibia) maintained their farming system despite being provided information that could have made them change it. Similar observations were made in Senegal where about 25% of farmers maintained their own system despite being provided agrometeorological information prior to the farming season (Roudier *et al.*, 2014). Amegnaglo (2015), based on a survey of empirical studies in Africa, observed that while some farmers do not respond to agrometeorological information, others adopt single or mixed strategies in response to such information. The proportion of such adoption they found is shown on Figure 2.2.

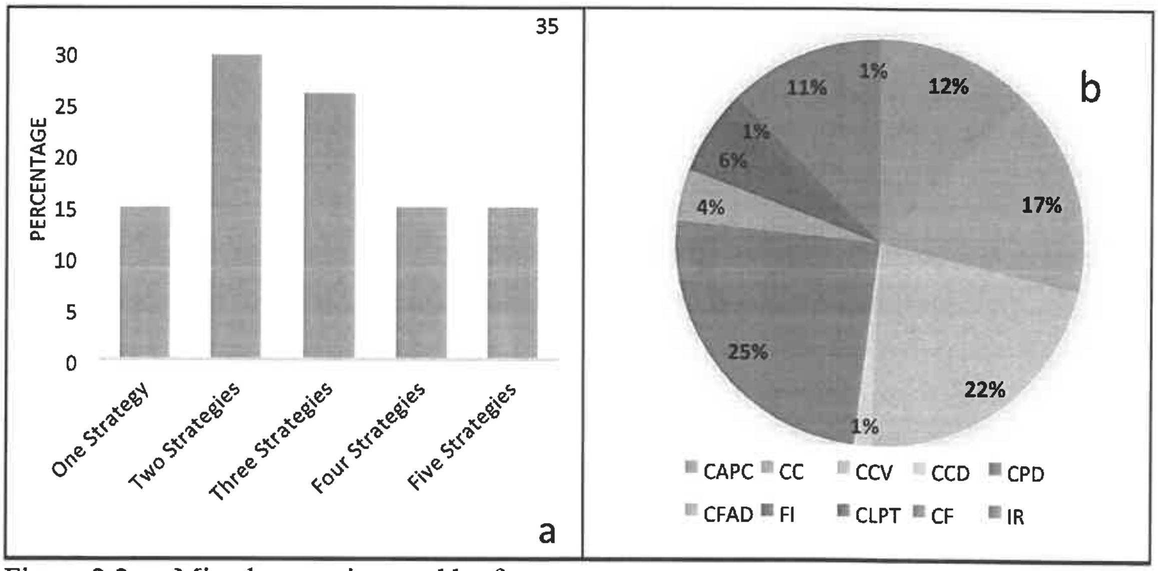

Figure 2.2: a. Mixed strategies used by farmers.

b. Proportion of the strategies farmers used. CAPC = change of area planted by crop, CC = change of crop, CCV = change of crop variety, CPD = change planting date, CCD = change of crop density, CFAD = change of fertilizer/chemicals application date, CLP = change of land preparation, CF = change of fields, CM = crop mix, FI = fertilizer intensification, IR = irrigation. Source: Amegnaglo (2015).

As Figure 2.2a. shows, the majority of farmers (30%) who respond to agrometeorological information mix two strategies, while one, four and five strategies are mixed by about 15%, while about 25% mix three strategies. In Figure 2.2b, the kinds of strategies used are illustrated. The authors contend that agrometeorological information that barely offers anything new hardly encourages any change in farmers' decisions. For example, predictions about impending dry seasons in places such as Niger or Lesotho were not useful to local farmers because they have grown accustomed to such seasons which are usually dry. They also observe that farmers found such information such as expected rainfall start dates to be helpful as it helps them make decisions about planting dates and ways to manage challenges they usually faced at the beginning of the seasons.

2.4 Agrometeorological information management and communication

A critical aspect of the use of meteorological information in agriculture is the methods and mechanism for managing and communicating such information to the end users in efficient and effective ways. This has been critical from the early stages of weather forecasting for agricultural purposes. In the United States, for example, free mail and telephone services were used to provide weather information to millions of farmers daily by the 1900s and radio broadcasts by the 1920s (Cahir, 2019). Literature indicates that this often draws on technological advances in agriculture and other sectors to aid the process. Over a decade ago, Weiss *et al.* (2000), for example, explored current and anticipated advances in information and communication technologies (ICTs), and their impact on the application of meteorology to agriculture. Weiss *et al.* (2000) argued that new ICTS will impact lives dramatically whether directly or indirectly, as current use of the internet, Geographical Information Systems (GIS) and satellite technology already indicates. These have immensely impacted every sector of life, including agriculture. Weiss *et al.* (2000) did not overlook the gap between nations as well as urban and rural areas concerning Information and Communication Technologies (ICTs) and communication of information through such technologies. However, Weiss *et al.* (2000) highlights contentions that the absence of or limited ICT infrastructure in many developing countries prove to be an advantage. In other words, these developing countries would benefit from highly developed technological infrastructure at the beginning rather than having to change installed outdated technologies.

Weiss *et al.* (2000) sites countries such as Gambia, Rwanda, Mauritius and Botswana as examples where the delays in accessing internet technologies has meant the instalment of the latest technologies, especially digital networks, which are faster than previous internet technologies already in use in other countries. This observation represents positive movement, but could undermine the urgent need for such technologies, especially for agriculture, in developing countries. Technologies are never static; new ones continually emerge that work better and faster than previous ones. Therefore, some of the technologies considered advanced in 2000 are now obsolete, and what is considered advanced today will become obsolete in a few years and obtaining advanced technologies at a later stage does not necessarily compensate for, or undo, the losses that could have been managed with the most basic technologies in previous years (Tubiello *et al.*, 2008).

A primary concern for studies such as Weiss *et al.* (2000) and Tubiello *et al.* (2008), is the communication of important agrometeorological information to farmers, and the observation that advances such as in radio technology will greatly impact this process. Several low cost and low-powered radio channels, radios which are not powered by batteries or use line voltage, are also now available at affordable rates, and can be utilized for dissemination of agrometeorological information to farmers. Tubiello *et al.* (2008) and several others offer examples of previously used systems for managing and communicating agrometeorological information.

One such example is the PestCast system, which was an initiative of the University of California's Integrated Pest Management (UC-IPM) project, the California Department of Pesticide Regulation and the United States Environmental Protection Agency (University of California, 2014). The project aims to reduce the use of pesticide by expanding the use of computer-based crop disease forecasting. The project provides an online database of interactive models and tools to assist farmers with decision-making on pest management based on their specific farm site conditions and requirements. These include daily, hourly weather data and long-term climate information from several stations in the region. Examples of pests and plant models on the site include the cotton planting forecast, sunset temperature, beet armyworm and more. These data are easily accessible to farmers digitally. A second example is the systems of the National Institute of Meteorology (NIM) in Brazil for communicating agrometeorological information to farmers (Okezie *et al.*, 2011). The institute's VISUAL TEMPO is a system through which real-time satellite imagery, weather forecast, and other meteorological information can be accessed by farmers through the internet or bulletin board systems. Another of the institute's system is the VISUAL CLIMA, where farmers can access rainfall information and monthly weather updates in the form of a bulletin. Users are able to download software needed to view such information at the meteorological institute's website at no cost.

The United Nations Food and Agriculture Organization (FAO) monitors global food security and provides data and early warning on food shortages globally. Through their Global Information and Early Warning System (GIEWS), it also provides climate and agricultural information for most African countries including satellite images, crop calendars and crop production areas. These are easily accessible through a website. In South Africa, daily weather information collected from many different weather stations is available on the website of the South African Weather Service. The FAO also has a fully operational project in South Africa as part of its technical assistance project which collects, analyses, and generates agrometeorological information products. The project is decentralized, well equipped and managed by well trained personnel in different Regional Early Warning Unit for Food Security within the South African Development Community (SADC). While these examples indicate advancement in the application of meteorology for agriculture and improved accessibility of such information, they also expose a substantial limitation in the methods of disseminating such information. Most of the technologies rely on the internet and web-based platforms for making such information accessible which could be a significant problem for farming communities without internet access or which have limited and slow internet connections. It also excludes farmers who are illiterate or are not able to interpret and understand such agrometeorological information and values. Thus, much more research is required to explore, implement and evaluate different models for managing and communicating agrometeorological information, especially to rural farmers in places such as Swayimane where the current study is located.

One empirical study that examined the production and communication of agrometeorological information to farmers and examined farmers' views and response to such information is the study by Kgakatsi and Rautenbach (2014). In this study, intermediaries were interviewed and used to disseminate early warning information from the Seasonal Climate Forecast (SCF) to farmers in South Africa in order to minimize the risks farmers faced. Such intermediaries included structures at the national and provincial levels, as well as agricultural unions. Kgakatsi and Rautenbach (2014) examined the different elements of early warning systems. These include, first, risk knowledge, regarding knowledge about the vulnerability of a community and the risk such a community encounters in the event of environmental, weather and climatic hazards. This also enables communities to prepare and prioritize needs. Second, prediction, warning and monitoring of potential disasters based on scientific data. Third, communication and dissemination of early warning information that is meaningful and useful to communities at risk, and fourth, the extent to which stakeholders are prepared to respond to or act on the warnings. The study found that most intermediaries (80%) including government officials, union leaders and other stakeholders view training and awareness-building programmes on climate and agrometeorology as the most important way of improving reception and meaningful understanding of agrometeorological information.

However, a few intermediaries from risk and disaster management group did not consider these as important. In terms of dissemination method and media, most of the respondents preferred mobile phones and text messages, but most respondents from government groups preferred electronic media because they have access to internet and computers and are able to exchange information via emails. The second most preferred method of dissemination was physical gatherings of farmers and extension workers during farmers' days. Over 85% of all respondents emphasized the need for established and functioning early warning structures to effectively manage and improve risk management in agriculture. Thus, Kgakatsi and Rautenbach (2014) concluded that improved structures and channels for timely and reliable seasonal climate forecasts for early warning are essential, and that feedback programmes need to be improved to enable intermediaries to better communicate relevant information to end users. While this study is very informative and addresses a crucial aspect of early warning and dissemination of meteorological information to farmers, it does not offer much insight into the perspectives of the end-users themselves.

Stigter (2010) sought to address this type of limitation in his study which collected data from small-scale farmers, extension officers, research stations and meteorologists to examine the integration of a wide range of agrometeorological knowledge and the delivery of such knowledge to farmers in countries where ICT infrastructure is low. Stigter (2010) further observed that agrometeorology in developed countries is more concerned with providing environmental information and data for the purpose of national policies and decision makers, for sustained development and food production, carbon sequestration in agroecosystems and the management of land management practices that affect greenhouse gasses. Stigter (2010) suggests that the advanced technologies these developed countries use could be transferred and be useful to developing countries. However, the different conditions of countries in the developing world require local innovation that seeks to address specific contexts. Moreover, the pressures from large populations and changing agricultural practice modes in developing countries means that such countries have greater responsibilities in implementing and benefiting from the application of meteorology to agriculture. These findings were corroborated through a later study by Stigter, Winarto, Ofori, Zuma-Netshiukhwi, Nanja and Walker (2013) who argue that new developments in agroclimatology learning and dissemination of information has improved farmers' responses to climate change. Lwande and Lawrence (2008) also affirm that the absence of integrated methods for processing and disseminating agrometeorological information to farmers at the local, small-scale level is a major and common problem in developing countries such as South Africa. The agricultural sector in these countries is unable to meet their potential despite improvements in agricultural technologies. This is because formal structures and systems are lacking expertise and wherewithal to integrate data from sources such as research institutions, agricultural agencies and meteorological stations with the actual requirements of the farmers and ecologies of these countries.

Lwande and Lawrence (2008) report on the result of their research among small-scale farmers in Kenya. They found that most farmers could not access relevant meteorological information, and where such information was available, the human expertise needed to meaningfully access and implement it was not available. Additionally, the dominant use of mass media, particularly radio, to communicate such information was found to be ineffective. They also noted that farmers perceive meteorological information, when available, to be inaccurate, and they cannot relate easily to the weather information they receive. Thus, they argue that expert systems need to be designed which have reasoning capabilities, and which also allow farmers control of and interaction with the sources of information. Moreover, the system should include an element that explains such information to farmers so that their perception of accuracy level will be improved (Stigter *et al.*, 2013). To address these limitations, Lwande and Lawrence (2008) propose an expert system model (Figure 2.3). This model illustrates a concept of an ideal model, which includes the farmers themselves as sources of information alongside research institutions, agricultural extension officers and meteorological stations.

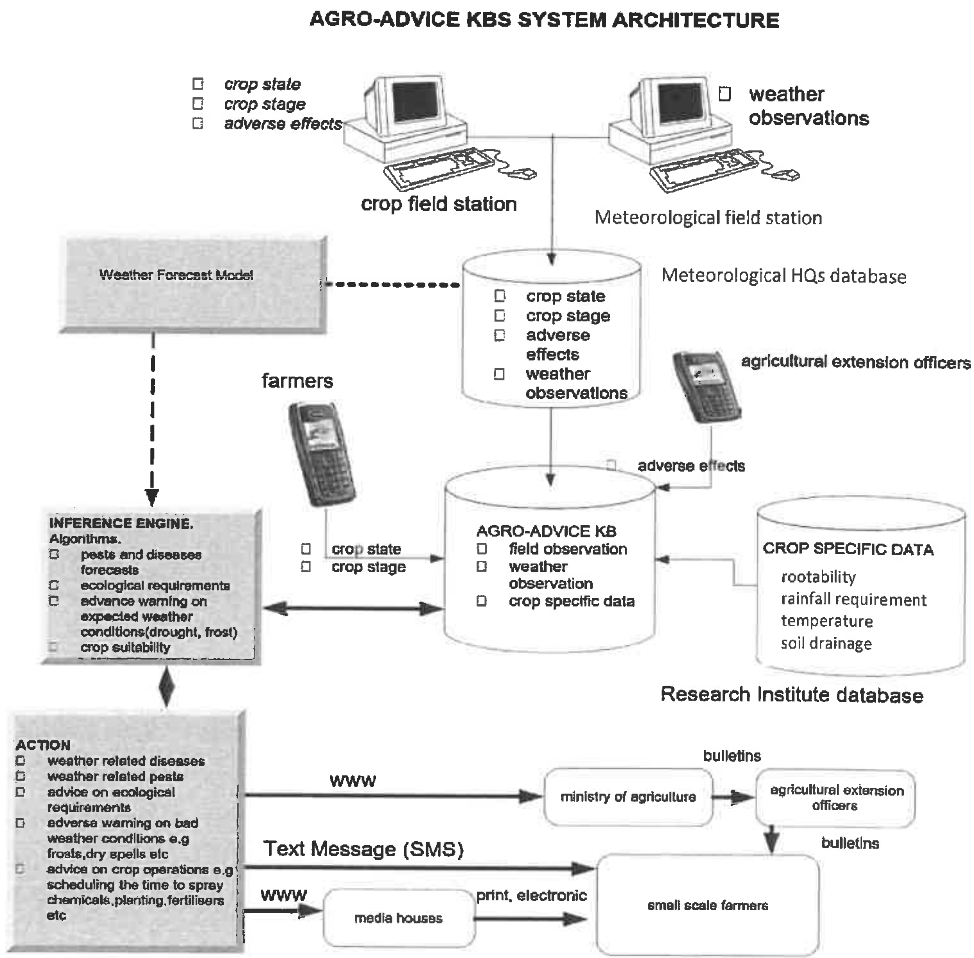

Figure 2.3: An example of an expert model
Source: Lwande and Lawrence (2008)

As illustrated in Figure 2.3, the knowledge that flows from these sources is collated in a Knowledge-Based System (KBS) and processed through algorithms and the small-scale farmers receive the output as well as interact with the expert system through text messages on their mobile phones. The information is further disseminated through mass media and the websites where government departments and other stakeholders can access and reproduce them in other forms such as bulletins.

The USAID (2012), noting that weather services are most necessary for farmers in Sub-Saharan Africa, observe that accessing reliable and regular weather information has been a major challenge in the region. Farmers have to depend on historical weather patterns despite increasing unpredictability of weather because of climate change. Thus, short-term weather information for 10 days or less and daily forecasts are crucial. This will be further helpful to farmers when information and advice are included when disseminating such information. In a study combining East and West Africa, Oyekale (2018) notes weather forecasts have changed farming operations through the introduction of risk mitigating measures timely implemented by farmers based on effective dissemination of information. This can be achieved through strategies such as attaching instruments for collecting weather information to telecommunication towers to reduce cost and enable real-time transmission of such data; training intermediaries at the local level to collect micro-level data and using simple instruments, transfer such data through their mobile phones, via Short Messaging Service (SMS), for further analysis. In terms of dissemination, the USAID (2012) argues that ICTs can be used to transmit simple weather information weather on a daily and short-term basis. They can be used to send information and reminders to farmers, for example "sunshine tomorrow, spray fertilizer or pesticide for a given crop" (USAID, 2012), and to issue alerts or warnings about impending extreme weather. Some of the key most effective ICT tools identified by the USAID (2012) include:

1) Radio, which can be used to provide qualitative information but which, however, is limited because the agrometeorological information cannot be personalized and does not usually allow direct interaction with farmers;
2) Mobile phones, which is considered to be the simplest and most cost effective. It makes it convenient to target a geographical location for dissemination of weather forecasts because phone numbers can be linked to telecommunication towers. Also, Interactive Voice Response (IVR) can be used, enabling the dissemination of such information through pre-recorded messages in the local language to make it more intelligible to farmers who are not literate;

3) Smartphones can also be very effective especially because they can use visuals to inform farmers, and receive feedback through mobile surveys;
4) Call centres, which are increasingly being established so that farmers can access more details and offer feedback.

Table 2.1 shows some examples of weather information platforms used in the dissemination of essential weather information to farmers.

Table 2.1: Examples of cases of weather information platforms.
Source: USAID (2012)

SELECT CASES OF WEATHER INFORMATION PLATFORMS	
Regional Initiative	
Toto Agriculture **Partners:** INSEAD Gates Foundation GSMA Farmers Voice Radio Grameen Foundation Others	This project has developed a content automation platform to provide access to localized agricultural knowledge in the world's poorest areas. Weather information is a key component that is delivered through SMS, MMS, video and radio. Highlights: • Uses satellite and weather station data from FORECA to create weather feeds. • Provides applications in data, video and voice (IVR) format in over 124 languages. • Highly scalable platform that can handle millions of SMS messages on a daily basis. • Geo-tagging by telecom tower location allows delivery of granular information within a reasonable distance.
Private sector service providers	
FORECA	A Finnish weather forecasting company provides digitized weather services to companies across the globe. Highlights: • It offers raw weather data feeds that provide weather forecasts, current conditions, and optional weather animations for any location worldwide. • Weather feeds can be accessed by coordinates or by location name (over 140,000 locations), and are available in 25 languages. • The interface is suitable for mobile applications, web applications and any other application that can receive and visualize online data.

SELECT CASES OF WEATHER INFORMATION PLATFORMS	
Ignitia Ltd	A technology company from Sweden that has developed an advanced forecasting model especially for tropical climates, which includes most of West and Central Africa. It is currently operating in Ghana and aims to expand across West Africa. Highlights: • Serves multiple customer segment including small-scale farmers, advanced farmers, and organizations with customized products; • Products include short term forecasts of up to 30 hours, rain forecasting, harvest forecasting and early warning alerts.
Delivery models for weather information	
Esoko	Esoko is a technology platform and consulting company that assists organizations to manage information flows. It currently works with partners in 15 countries across sub-Saharan Africa. It offers a package of information services for farmers that includes weather. The weather information comes from content providers such as Toto Agriculture. Highlights: • ICT products include bulk SMS messages, automated alerts and field alerts; • Clients include individual farmers, businesses, NGOs and government.
Mobile Weather Alert **Partners:** Uganda Department of Meteorology, World Meteorological Organization, Grameen Foundation, National Lake Rescue Institute	A pilot project to support the decision-making processes of Ugandan farmers in the Kasese region and fishermen on Lake Victoria. The project involves two-way communication between Community Knowledge Workers and end-users. Advisory information is informed by 10-day, monthly, and seasonal forecasts, and shaped by farmers, who give input on the type of information that would be most helpful. Highlights: • Two-way information flow, • Weather information combined with specific advisory information; • Awareness and training for farmers and other stakeholders.
Bangladesh Friendship Education Society - Community Climate Care Centres	This project proposes a network of local sources of information for farmers, both through mobile technology and at the centres themselves. In an effort to assist farmers in vulnerable communities adapt to climate change, the centres will be equipped with internet-accessible computers, video conferencing, and other low-

SELECT CASES OF WEATHER INFORMATION PLATFORMS	
	cost ICT systems to connect local farmers to national and localized weather information.
Noula	Noula is an interactive crisis and needs-mapping platform developed by the Haitian ICT company Solutions in response to the 2010 earthquake in Haiti. Noula provides a channel for two-way communication between remote communities and service providers, using a call centre where extreme weather information is simultaneously received, analysed and geo-located, then provided to vulnerable Haitian communities.

In an extensive review of literature on the generation and dissemination information to farmers in Nigeria, Sani *et al.* (2014) further observe trends that reflect the experience in other parts of Africa, including South Africa. They observe that scientific information relevant to agriculture is often generated in research institutions and universities. However, they also observe that agricultural information innovations often are not implemented with the farmers in mind which makes it difficult for farmers to be aware of and access such information. They note that extension workers are the most identified source of information by farmers, but farmers, similar to Lesotho, found print media to also be useful sources of information. While there is growing use of ICTs and mobile phones to disseminate useful information to farmers, there is also a strong reliance in Nigeria on traditional sources of information especially among older farmers, who draw on past experiences and familiarity with weather patterns. Sani *et al.* (2014) use the broad term 'agricultural information' which does not offer much information specific to the generation and dissemination of agrometeorological or weather information to farmers.

Joto Africa (2011) reports on climate communication and adaptation in Africa and strategies used to generate and communicate data in different parts of Africa, including those that involve the farming communities in the process. In Niger, for example, Ababale (2013) reports that over 20 raingauges have been installed in communities by the Adaptation Learning Programme (ALP) which also linked these gauges to a community early warning and vulnerability system through mobile phone services. Trained monitors from the community are involved in measuring, recording and disseminating daily amounts of rainfall to the local agrometeorological services using their mobile phones.

The meteorological service analysis these data and transmits the information for further dissemination through national and community radio channels. This has enhanced decision making and improved farming as almost every farmer in the selected community has access to such information through community radio (Ababale 2013). Similarly, Mwesigwa and Omukuti (2013), as well as Nderitu and Ayamga (2013) report on similar strategies in Ghana and Kenya respectively. In addition to mobile phones and radios, these authors report on the use of agro-advisories. This involves the dissemination of agrometeorological information before rainfall seasons begin. It is a community level approach that involves extension workers, farmers, project coordinators and community leaders. Together, the forecasts for previous seasons are evaluated, followed by a sharing and harmonizing of scientific and traditional weather forecasts for the coming season. Advisories from agrometeorologists are discussed and agreements are reached by all participants about agro-advisories. These include effective farm management practices, planting time, inorganic fertilizer choices, farm manure use, crop suitability and types, weeding, pest and disease prevention and control measures, among other things. Advisories are also used in various other parts of Africa. According to Sivakumar (2006), agrometeorological units generally present their information and findings in text formats, including graphics and often agricultural extension and research workers and agencies are not involved in preparing such bulletins and disseminating them. Moreover, over 80% of such bulletins primarily target government agencies, NGOs and other organizations, and only a few target farmers.

Intasave Africa (2015) reports on the Adaptation at Scale in Semi-Arid Regions (ASSAR) project, which is implemented in five institutions globally, including the University of Cape Town, South Africa. The report offers a helpful illustration and categorization of the users of climate information in Africa and the most effective ways of communicating with these users tailored to their specific needs. It also advances the integration of modern and indigenous climate and weather information. Table 2.2 illustrates these users and suitable communication strategies.

Table 2.2: Categories of users of agrometeorological information and dissemination strategies tailored to meet their needs.

Source: Intasave Africa (2015)

USER	COMMUNICATION FORMS AND FORMATS	CHANNEL	AIM	SOURCES
Policy makers	**Form** *Written content:* • Policy briefs • Issue briefs • Position papers • Working papers	□ Web content □ Policy magazines	□ Inform policy formulation □ Influence adaptation and mitigation actions	Katz (1957), Nisbet & Kotcher (2009), Hine et al. (2014), Moser (2014), CARE International (2014), BBC World Service Trust, (2010), World Bank, (2011).
Community members	*Written content:* □ Reports and magazines	□ Community meetings and workshops □ Intermediaries	□ Inform and support behaviour change in communities □ Inform communities about appropriate adaptation actions	Kristjanson et al, (2014), Bisht and Ahluwalia (2014), Moser and Dilling (2012), Nyamba and Mlozi (2012), BBC World Service Trust (2010)
	Verbal audio and visual content: □ Plays and music	□ Radio and television □ Farmer field schools □ Mobile phones		
	Verbal face-to-face engagements:	□ Community meetings and workshops □ Intermediaries e.g., extension workers		

USER	COMMUNICATION FORMS AND FORMATS	CHANNEL	AIM	SOURCES
Practitioners	**Written content:** • Reports and other publications • Peer-reviewed scientific papers • Application tools e.g., vulnerability assessment tools **Verbal oral:** • Face-to-face communication	Knowledge platforms and websites Field demonstrations e.g., through farmer field schools	To influence adaptation and risk mitigation measures Inform and support behaviour change	CARE International (nd), ALIN (2013), Luganda (2002), Panos Eastern Africa (2011), (Kristjanson et al. (2014); Harvey et al. (2012), Moser (2014), Moser and Dilling (2012), IFRCRCS (nd)

Table 2.2 illustrates that all stakeholders have the same needs for information and thus, not all communication strategies are effective to everyone. The report agrees with most of the literature reviewed in this section that suitable strategies including the use of mobile phones are crucial and useful for dissemination of agrometeorological information to small-scale farmers.

2.5 Chapter summary

This chapter reviewed literature on climate change, its impact on agriculture, the strategies for mitigating such impacts, and the use and communication of meteorological information for effective management of the impact of climate change and for sustainable food production. The studies reviewed showed that much has been achieved and advances have been made in this regard in Africa, but more so in developed countries. However, African countries are still highly challenged in their ability and capacity to adopt innovative and ICT-based strategies for sustainable food production. Additionally, while mobile phones are being used to disseminate weather conditions in different parts of Africa, the review in this chapter indicates that the most widely used dissemination methods include radio broadcasts and contacts with extension workers. Thus, more studies such as the present one are needed to further explore the potential of cell phones and the challenges in using them, since they are cost effective among several other advantages, as the study has shown. The next chapter discusses the methodology used to undertake this research. This includes the discussion of population and sample characteristics, data collection and analysis procedures as well as the ethical principles observed in the process of collecting and analysing data.

Chapter 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides further background to the area of study, including demographic and bioclimatic information about Swayimane and the UMDM. Details of the AIM system, the AWS installation and the types of data they measure as well as how these data are disseminated are further discussed. The chapter further explains the methods and techniques used to interact with local farmers in Swayimane and to collect and analyse empirical data for the study.

3.2 Study area and the AWS system

3.2.1 Demographic information

According to the 2011 census (Statistics South Africa, 2012), Swayimane has a population of about 12 000 (316.01 per km^2) and 2 000 households. The female population is 53.14% and 46.86% is male. The community is almost exclusively black African (99.75%) and Zulu speaking (96.55%)[2]. Preliminary and cursory survey of the location indicates that Swayimane is a poor community with small-scale subsistence farming activities, and a largely uneducated population. The community is also located in the UMDM, an area in which climate projections predict a warmer future and unpredictable changes in the annual rainfall as well as flash floods and storms (CNA Military Advisory Board, 2014). Floods, severe storms and wildfires are already currently experienced by communities in the UMDM. Thus, the projections are of immense concern because they indicate an increased risk of these climate-driven events, including potential increase in drought events. A preliminary and cursory survey indicates that Swayimane is a poor community with small-scale subsistence farming activities, and a largely uneducated population. Figure 3.1 shows a 3d-aerial view of Swayimane, the target geographical area for this study.

[2] https://census2011.adrianfrith.com/place/562031

Figure 3.1: A 3D satellite view of Swayimane
(Source: google maps).

3.2.2 Bioclimatic information

Swayimane is in the subtropical coastal climate zone and consistent with a savanna biome. The climatic characteristics of the savanna biome are represented in Figure 3.2.

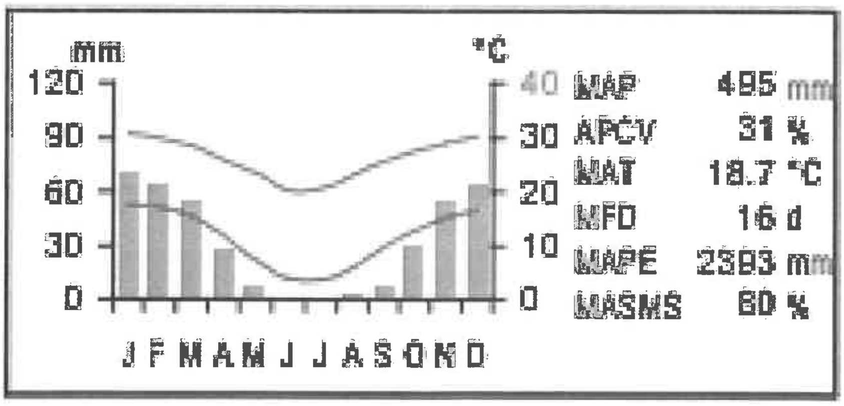

Figure 3.2: Climatic diagram of the savanna biome.

The blue bars indicate the median monthly precipitation the two red lines are the mean daily minimum and maximum air temperatures. Also indicated are the mean annual precipitation (MAP); the annual precipitation coefficient of variation (APCV); the mean annual temperature (MAT); the mean frost days (MFD) with screen temperatures below 0°C; the mean annual potential evaporation (MAPE) and, the mean annual soil moisture stress (MASMS) (Rutherford et al., 2006).
(Reproduced from Rutherford *et al.,* 2006)

Swayimane is in the Misbelt bioclimatic region (region 3) with a good supply of water, cool and moist weather, and average air temperatures of between 16°C and 18°C and annual precipitation below 1000 mm (Matungul, 2000). Additionally, the area is suited to cropping forestry as well as intensive livestock production, and generally has a large potential for agriculture (Matungul, 2000). The uMgungundlovu District Municipality (UMDM) is generally assessed as facing high risk of climate change which increases the vulnerability of the communities and farms (CNA Military Advisory Board, 2014). Climate projections predict a warmer future and unpredictable changes in the annual rainfall as well as flash floods and storms in the UMDM as a result of the limited rainfall (CNA Military Advisory Board, 2014). Floods, severe storms and wildland fires are already currently experienced by communities in the UMDM area. Thus, the projections are of immense concern because they indicate an increased risk for these climate-driven events, including potential increase in drought events.

3.2.3 The automatic weather station (AWS) and web-based system

The mounting of the automatic weather station at Swayimane high school followed the principles and standards of the World Meteorological Organization (WMO). It included the mounting of a mast which had to be on a flat cleared surface, without the interference of any tall plants or trees. The mast has an enclosure packed with a CR3000 datalogger (Campbell Scientific, Logan, USA), a modem, a barometer, battery and a power regulator. Several sensors were installed, including the solar irradiance sensor facing the sun; air temperature and relative humidity sensor placed at a height of 2.5 m; leaf wetness sensor (attached on the tripod, 150 mm high); soil sensors at different depth levels in the ground, and wind speed and direction sensor with the wiring box facing the true south and the wind vane facing true north. This was also tested for positional accuracy. The solar panel was also installed facing north at midday so that it could receive maximum solar radiation. A few centimetres away from the mast is a rain gauge to measure rainfall. The inclusion of leaf wetness sensor and three soil sensors and its connection to a nearby soil-water station for measuring soil temperature from a different project, makes the Swayimane AWS system to differ slightly from traditional AWS systems. Thus, it could additionally measure soil temperature, current drain, electric conductivity, volumetric water content and dielectric permittivity. Figure 3.3 shows a picture of the AWS system installed at Swayimane High School.

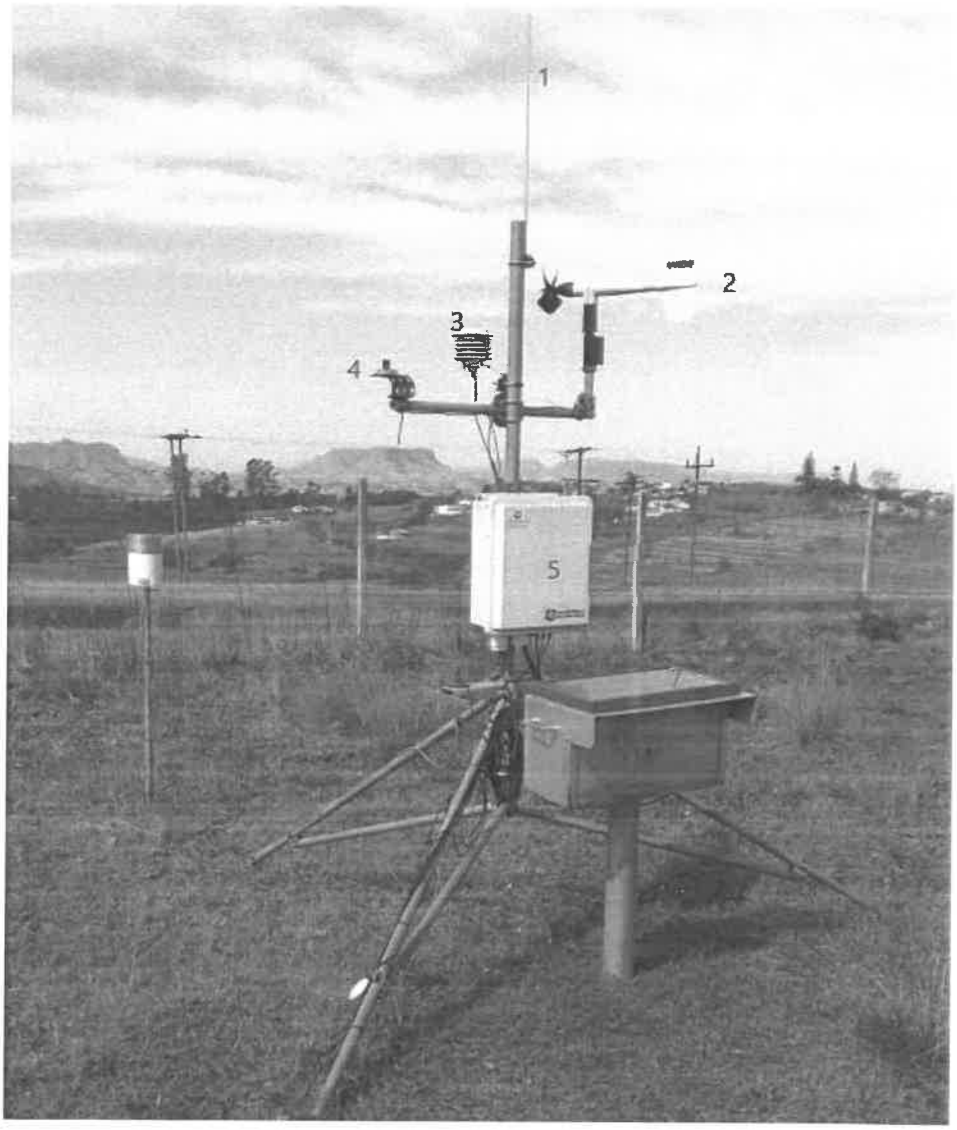

Figure 3.3: A picture of the AWS system installed at Swayimane High School with its different components

1) Lightning rod 2) Wind direction and speed sensor 3) Six-plate Gill Shield 4) Pyranometer 5) Enclosure 6) Rain gauge 7) Solar panel 8) Leaf wetness sensor 9) Soil sensors.

3.2.4 Collation and dissemination

The data collected through the agrometeorological instrumentation mast in Swayimane is transmitted to a server at UKZN and published on a website[3] for near real-time viewing (Mengistu *et al.,* 2014). The site is powered by the professional version of the Real-Time Monitor and Control Software (RTMC Pro) by Campbell Scientific[4]. The description on the Campbell Scientific website indicates that this software has real-time monitoring and control capabilities that allow the creation and publishing of graphical screens. With large interactive components libraries such as alarms, switches, charts, gauges and status bars, RTMC Pro is relatively easy to use to design agrometeorological weather information displays. It also includes an inbuilt CSI webserver and a web publisher that makes it easy to publish RTMC projects online over the internet or intranet. Additional features of the RTMC Pro software used include multiple Logger Net Servers, LNDB databases, HTTP data loggers, Campbell Scientific data files and virtual data sources which allow multiple-source viewing of data. Reports can also be created using historical data and exported, and the several mathematics and logic expression are included in a library that enables the user to convert data for display purposes.

The data collected from the system are also visible on a smart television screen installed at Swayimane high school. Thus, the AWS system and the streaming of agrometeorological information at the school site enables the linking of learning at the school with e-learning, as well as with the diffusion and transmission of relevant agrometeorological information to the wider community by students, who, it is hoped would take advantage of the systems to understand such information and assist their parents and community.

[3] http://agromet.ukzn.ac.za5355/Sw_weather/index.html
[4] https://www.campbellsci.co.za/rtmcpro

As Figure 3.4 shows the website and the television screen display the relevant data in very friendly and readable visualizations. Data about various parameters including relative humidity, air temperature, leaf wetness, solar radiation, wind speed, wind direction, atmospheric pressure and solar radiation. Sensors measuring soil water content and the leaf wetness provide data that can assist with prediction of incidences of disease and flooding.

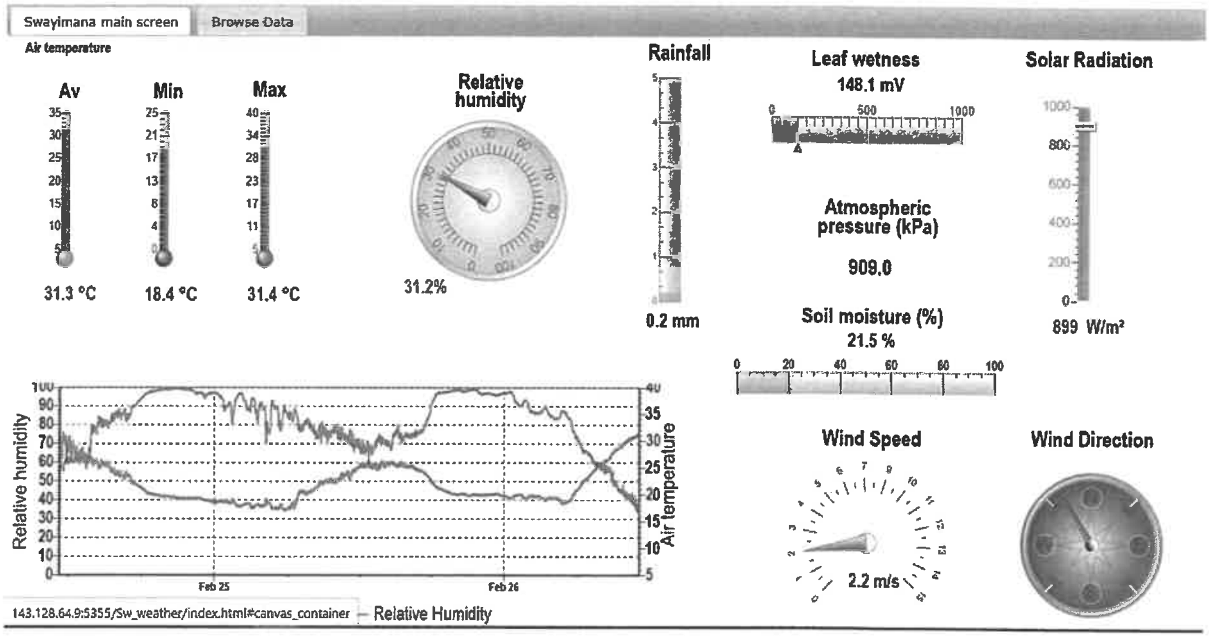

Figure 3.4: Example of information displayed on the installed screen at Swayimane High School

Online at http://agromet.ukzn.ac.za5355/Sw_weather/index.html.

In addition to the agrometeorological parameters measured and other information displayed on the screen and website, different types of datasets are made available on the website in alphabetical order for reference, analysis and other types of usage. The screenshot shown in Figure 3.5 is an example.

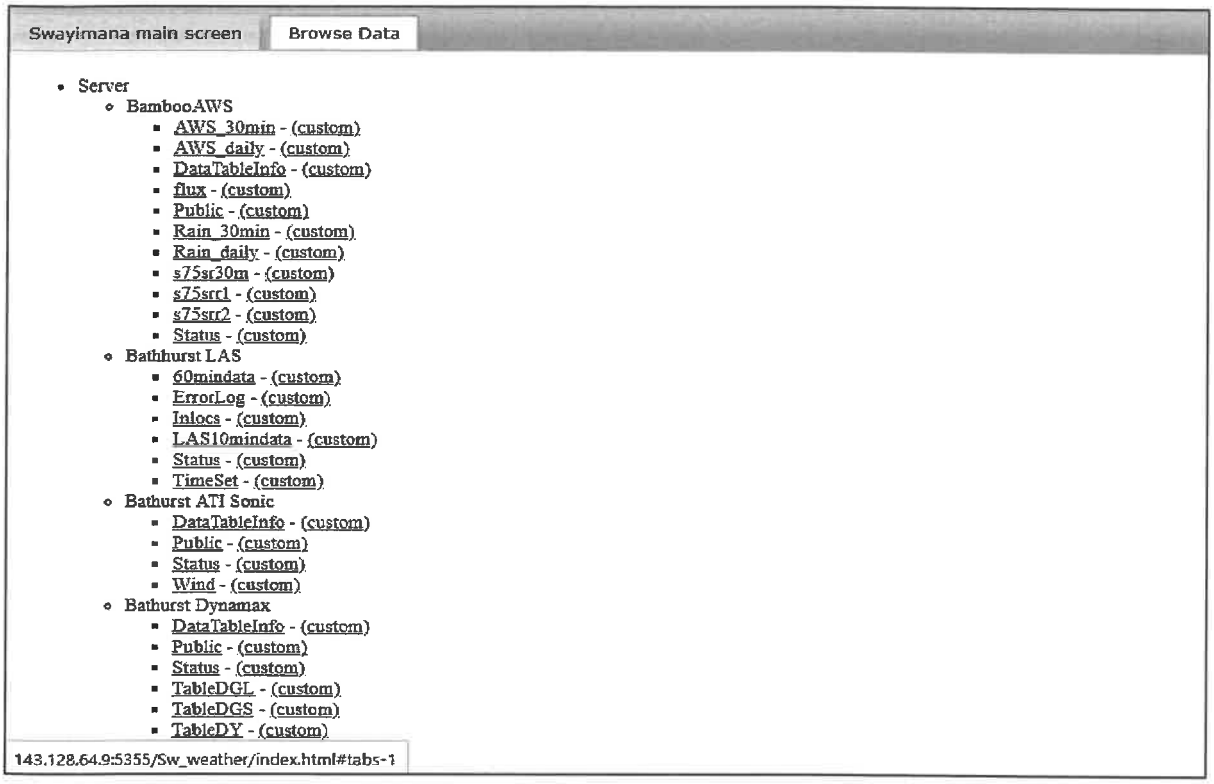

Figure 3.5: Example of datasets available on the Swayimane weather link

3.3 Research approach and process

A qualitative, dialogical approach was adopted for this study to enable a closer interaction with farmers and to bring the agrometeorological information much closer to them and increase their understanding and usage of such information. It was also meant to allow a closer analysis of the interaction of farmers with the uMgungundlovu District Municipality pioneered URP's AWS and the information it provides, since many of the farmers are not literate and would not easily interpret and apply the provided information. Qualitative research prioritizes the experiences of participants and the research population; it is often interpretive and allows the researcher access to in-depth information and personal feelings and responses to the issue or event being investigated (Bernard, 2017; Brannen, 2017).

To complement the URP's already established dissemination method, meetings with local farmers were organized in the Swayimane community hall. These were held on March 14, June 26 and August 15, 2018. These meeting forms part of the selection process of the respondents. From the farmers that attended at different times, six respondents were chosen to take part in this study. These six participants were asked series of questions as detailed in the questionnaire given. This form of information dissemination and interaction was chosen with the awareness that relevant information was being disseminated at the Swayimane High School and online, but farmers are yet to fully take advantage of this due to several limitations, such as inability to read and interpret such information. Moreover, other systems initially envisioned such as short messaging service (SMS) which would deliver weather information directly to farmers, and more conveniently, were not yet functional. The purpose of the meeting was clearly explained to the farmers and their consent received for the meeting to continue as part of a research project. At the meeting, the researcher talked to the farmers about the automatic weather station (AWS), the types of data it receives and its function. More importantly, the purpose of the system in their community, how the information from the system is disseminated and the ways the farmers could take advantage of such information to improve their agricultural activities, food production and general well-being, was explained to them. Questions raised by the farmers were also addressed to the best of the researcher's knowledge and abilities. This phase of the research prepared the farmers to better respond to questions posed to them in the later phases of the research and to contribute better to the analysis of aspects of the URP project relevant to this research. Figure 3.6 shows a sample of the notes used by the researcher at the meeting with farmers.

Automatic weather station....... The automatic weather station is made for measuring several meteorological parameters. It is designed and built for the long-term use under extreme weather conditions without any infrastructure. The AWS can be equipped with diverse sensors

Some of these sensors installed on dis are

A. Wind speed and wind direction
B. Leaf wetness sensor
C. Air temperature sensor
D. solar radiation sensor
E. Relative humidity sensor
F. Rainguage
G. Soil moisture

The purpose of installing the automatic weather station was to link the collection of weather data to learning and e-learning at Swayimane High School through UKZN's School of Agricultural, Earth and Environmental Sciences.

The station is capable of collecting meteorological information using maximum and minimum temperature; maximum and minimum relative humidity; wind speed and direction; solar radiation, rainfall and reference evapotranspiration (the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants).

The system is also connected to leaf wetness sensors and soil water content sensors that can be used to predict disease incidence and flooding.

Figure 3.6: Sample of notes prepared for meeting with local farmers at Swayimane[5]

3.3.1 Sampling techniques

A non-random sampling technique, purposive sampling, was used in the selection of participants for the study. According to Elmusharaf (2012), in purposive sampling, the researcher chooses a sample that he/she thinks is representative of the population. Sharma (2017) notes that the key advantage of purposive sampling is its ability to allow the researcher to select a sample from individuals who are most knowledgeable about the subject matter and can provide relevant information. However, the technique has also been found to be prone to researcher bias (Sharma, 2017:751). The primary selection criteria were that participants had to be farmers residing and farming in Swayimane and had participated in the meetings held with the researcher. They therefore had some knowledge of the AWS, its purpose, functions and possibly had used information based on data from the system. Once study participants were selected, data were collected through a combination of Key Informant interviews (KI) and Focus Group Discussions (FGDs).

3.3.2 Method of data collection

[5] The researcher made attempts to simplify the information on this note and to demonstrate the relevance of such information to the farmers

Data were collected through semi-structured interviews with six (6) farmers in the Swayimane community. Interviews are one of the primary methods of collecting data in qualitative studies because they facilitate the collection of rich and comprehensive data and allow the researcher to follow up with further questions when necessary (Silverman, 2016). The interview questions were open-ended and sought, at the beginning, to gather brief biographical information about participants, including who they were and how long they had lived in Swayimane. This was followed by questions aimed at gathering information central to the study, such as how long they had been involved in farming, how much farming they did, their thoughts on how weather affects farming, whether the AWS system and information is gathered had made any difference to their farming practices, the information they found most helpful, and the method of dissemination they found most helpful, among other things.

3.3.3 Method of data analysis

The translated responses of the research participants were analysed using thematic content analysis. Content analysis is a technique used to organize, interpret and make valid inferences on research data (Bengtsson, 2016). It involves the systematic coding and assessment of qualitative data and determining the presence or occurrence of certain words, phrases, issues, expressions, among others within a dataset, which are then categorized and organized into themes Graneheim et al. (2017). Content analysis is very flexible and limits the interference with data as a result. Thus, the data for this study were closely read several times to develop a good level of familiarity and understanding with the text. This was followed by colour-coding of words, phrases and lines that were prominent or recurred and which were in line with the objectives of the study. The coded contents were then organized into themes guided by the research objectives. The result of this analysis is presented in Chapter 4.

3.4 Conclusion

The methodological processes and techniques utilized for this study have been detailed in this chapter. The next chapter will present and discuss the results/findings from this process.

Chapter 4: RESULTS

4.1 Introduction

This chapter presents the result of the study. It begins with the demographic details of the research participants followed by the results of the study which were analysed and presented thematically. Thus, some of the themes that emerged from the data collected from farmers include the challenges they experienced as farmers, consciousness of weather conditions and their impact on their farming and farming decisions, their assessment of the research process and methods of dissemination, and their preferences regarding reception and access to weather information.

4.2 Demographics, farming preferences and behaviour in Swayimane

Participants were asked a set of questions that aimed to understand them as members of the Swayimane community and to their life and work as farmers, how long they had been farmers, how much farming they did, what kinds of farming they did and what challenges they faced, among other things. Table 4.1 shows a summary of basic information about the research participants.

Table 0.1: Demographic information of participants

Respondents	Age	Occupation	Length of occupation	Length of stay in Swayimane	Family status
1	38	Farmer	Since primary school	Place of birth, Most of life	Single parent, with 5 children
2	45	Farmer	15+ years	More than 30years	Has 4 children
3	52	Farmer	20+ years	Entire life	Married to 2 wives, with 12 children
4	50	Farmer	25+	Over 45 years	5 children
5	47	Farmer	Entire life	From birth	5 children

6	55	Farmer	20+	Entire life	Single parent with 6 children

These were farmers who had participated in the information and dialogue sessions organized by the researcher for the purpose of this research. Three of the participants were in their early to mid-50s, two in their 40s and only one below 40. This is also a fair representation of the estimated age range observed among the farmers who participated in the organized information sessions. These participants also reported farming as their primary occupation. Four of the participants were born and had lived their lives in Swayimane, while two said they had lived there most of their lives (over 30 and over 45 years). They also had been involved in farming for a minimum of 15 years, with most of them having farmed for over 20 years or for most of their lives. This indicates that they were significantly experienced farmers and depended on their farming activities for subsistence, income and to care for their families. As one participant noted,

> *In my home we have been surviving through farming since my primary schooling* (Participant 1)

And another said,

> *I live on farming, farming is my life* (Participant 5)

Thus, farming is central to the lives of these farmers and very important to them. Additionally, considering the poor nature of the community, some of the farmers can be said to have relatively big families. Five of the farmers interviewed had 3 to 6 children, and one had 12 children and was married to two women.

In terms of the nature of their farming activities, participants reported farming a variety of crops and some livestock. The crops mentioned include mealies, beans, vegetables, cocoyam, sweet potatoes and livestock include cattle and goats. All the participants appear to farm sizeable fields or more than a single field some of which came as inheritance from family. Participant 4 for example mentioned that,

> *I have six fields that I farm on, where I plant mealies, sweet potato, cocoyam, beans etc.*

And Participant 5 said,

I farm a very big inherited family land

These show that participants have considerable involvement in farming and have sizeable stakes in it.

4.3 Challenges experienced by farmers and the impact of weather

The next set of questions that the research participants were asked aimed to understand what challenges they faced as farmers and to also understand whether, and to what extent, they consider weather conditions and variability to impact/affect their farming activities and outcomes.

With regards to challenges, the primary concern of the farmers in Swayimane is the experience of poor yields after they had invested much time, energy and resources. This also appears to happen more frequently than they expected or desired. As summarized by Participant 5,

The challenge is that sometimes our work/farming is in vain or yield no results.

Participants acknowledged that sometimes there were good harvests, and that their output usually fluctuates between expected/befitting and poor produce. However, the failure of crops appears to be of critical and growing concern to the farmers. One participant further mentioned the death of livestock as a challenge and that they did not thrive, forcing him to sell or downsize to avoid further losses. The participant did not explain or indicate that they knew the causes of such death or lack of flourishing of his livestock. Another participant mentioned unpredictable weather conditions as a significant problem, noting that sometimes after planting they experience little or no rain and extreme heat, which kills the crops.

When asked specifically about whether they thought weather conditions affected their farming, participants all agreed that it did. Participant 1, for example, observed that,

Weather conditions have big impact on our farming, as some plants wither and die, no produce obtained.

The farmers did not demonstrate any nuanced or detailed knowledge or understanding of weather conditions and the different ways they impact their farming. However, they were aware of variability and the increasingly unpredictable nature of the weather, especially rain, which does not always fall when they expected or hoped.

Thus, for the interviewed farmers, fluctuating and poor yields, and unpredictable weather conditions constitute major challenges to their farming and life generally since they are heavily dependent on farming. These challenges also make sustainability a challenge.

4.4 Dissemination of agrometeorological information and reception by farmers

As explained in Chapter 3 the present research utilized strategies that complemented the already established method of disseminating the agrometeorological information collected through the AWS at Swayimane. This was done with the awareness that while it is hoped that students at Swayimane high school would eventually be able to interpret the weather information displayed on the TV screen at their school. Also, that it would be integrated into some of their learning, and through them, the relevant information would reach their families and other farmers in the community, there is still much to be done to achieve this. Farmers were yet to fully take advantage of the system, and other systems of dissemination initially envisioned, including short messaging services (SMS) delivered directly to farmers' mobile phones are yet to be functional. Thus, the researcher, with the help of an interpreter, organized sessions of meetings with farmers to share relevant information, and interact with the farmers, giving them the opportunity to deepen their understanding and to ask questions.

4.4.1 Consciousness of the impact of weather conditions and change in planting decisions

All the farmers interviewed agreed that they had become more conscious of the fact that changes in weather conditions affect their farming activities and of the need to take this more seriously. The central way this knowledge has shaped their farming behaviour is observed in their planting decisions and the preservation of livestock feeds. They report being increasingly more deliberate about what they plant after considering the weather condition. For example, participant 2 said,

> *There is a change after gaining knowledge about weather conditions and relationship it has with farming. I choose what to plant and caring for my stock accordingly and keep stock feeds to avoid hunger during drought.*

Thus, learning about weather conditions made a difference to these farmers, at least in deciding what to plant and when, in order to achieve fruitful harvest. The farmers did not suggest that they had gained sufficient or detailed knowledge of weather conditions, and the study did not seek to establish how much they knew. However, they seemed to have acquired an amount of knowledge that is able to inform their planting decisions.

The researcher also sought to understand whether, and to what extent, they had taken weather patterns into consideration in making agricultural decisions prior to the installation of the AWS and the information meetings. The participants reported that they had planned their farming activities based on seasons and what crops they knew were planted in each season. Participant 1, for example noted that,

> *I was working on assumption according to seasons, that if it is winter, I plant seeds that do not need lot of water like sugar beans, since I had no detailed knowledge of weather to carefully consider it.*

And Participant 3 responded,

> *Weather conditions were not taken into consideration, I was just planting anyhow with the aim to care for my family.*

The farmers did not take immediate and long-term weather patterns and fluctuations into account. They planted according to the seasons and expected good yields but were also aware that the weather did not always work as planned, especially regarding shortage of rains and excessive heat. Thus, prior to learning about weather, they had limited information on which to pre-empt the outcome of their yields and make decisions accordingly.

4.4.2 Most useful information and further access to weather information

The preceding section already indicates that participants found the new weather information they acquired to be useful. However, the researcher also attempted to find out which specific information was most helpful, and which was least helpful. Participants mostly responded in general terms, primarily highlighting that being informed of weather conditions and how they relate to and impact farming was what they found most helpful. This is demonstrated in the following excerpts:

> *Being informed of weather condition, the relationship it has with farming and its impact on farming (Participant 1).*
>
> *To consider weather conditions before embarking on farming and type of seed suitable (Participant 3).*
>
> *I found it useful that I need to understand weather conditions before planning what to plant on the soil (Participant 6).*

It seems, therefore, that rather than any specific information about weather conditions, farmers found it quite helpful to know that weather conditions affected their farming in ways they did not previously think about, and that such knowledge can significantly improve their farming and produce.

On the other hand, participants found it least helpful that such weather information received during the information session would not be regularly available and accessible to them. Almost all the participants felt that the purpose of the project would be defeated since they are unable to receive weather information consistently and in an easily understandable and interactive manner as they did during the information session. For example, Participant 4 observed that,

> *It is not helpful to know that this weather information cannot be accessed always.*

And like other participants, Participant 2 agrees that,

> *What seems a challenge still is that the weather information will still remain inaccessible after the information sessions.*

Although the type of weather information shared with the farmers is consistently updated online and displayed on TV at their community's high school, the farmers did not see that as accessible to them and found information sessions and conversations led by the researcher to be more accessible and a useful learning experience to them. They also expressed a desire and preference to continue to access weather information this way.

Participants further expressed the desire to know precisely where and how they could access weather information easily and on a daily basis. Thus, when asked what other information they thought might be useful but had not received as at the time of the interview, the following responses were given:

> *Yes, to know how and where we can access this information on daily basis in future (Participant 3)*
>
> *Yes, how can we access weather information on a continuous basis? (Participant 4).*

Besides these examples concerned with continuous and regular access, participants also highlighted other issues they would like to learn more about. For example:

> *We still need information about type of seeds suitable for our soil along with weather condition as it may be related to produce (Participant 1).*
>
> *Yes, it is that how can one know as to when the weather condition will change and for how long will it remain the same before planting? (Participant 5).*

These responses indicate an interest in further learning about how to make decisions on what seeds to plant based on the nature of their soil and its suitability to certain crops, and how to better predict weather conditions, changes in weather and the periods that specific weather conditions might occur. These and other issues interest the farmers as they could see from knowledge gained that weather conditions and variability matters and can make significant difference in their farming.

4.5 Methods of dissemination

Participants were asked to evaluate the information sessions as a method of disseminating weather/agrometeorological information to farmers. The participants generally had a positive response to this. They felt that the meetings were helpful to them and enabled them to not only receive information but to generally improve their knowledge and experience. The major reasons for their positive assessment of the method of dissemination was the fact that it was direct, easy, interactive and allowed them to ask questions for clarity. This is reflected in the following excerpts:

> *The method of information dissemination was much easier as it was direct from the source and we were able to ask questions for clarity (Participant 1).*

It helped a lot the method the information was given to us as it was direct from source and opportunity was afforded for us to ask questions (Participant 2)

Much of communication was possible during the meetings with farmers only because there was an interpreter who bridged the communication gap through her interpretation from isiZulu to English and vice versa. While participants did not explicitly mention this fact in their assessment of the process, the fact that they received communication in their own language could be seen as crucial to their ability to participate and benefit from the process, and why they saw it as an "easy" process.

However, being aware that this was a temporary event and that they would continue to need such weather information in a clear and relatable manner, participants expressed their desire to be able to access weather information themselves, directly, regularly and continuously. Thus, Participant 3, for example, said,

if this weather information can be accessed in our area without waiting for anyone to come once in a while

Participant 6 also suggested as follows:

Yes, it will be better for us to access weather information on our own on a continuous basis.

The farmers want to be able to more conveniently have the relevant weather information their own time and regularly. Additionally, they repeatedly asked about the possibility of installing a system for them as farmers in their area, outside the school, that they would be able to interpret on their own, without having to wait for their children or others to inform them. This is highlighted in the following quotes from Participants 2 and 4:

If we can have a weather information system installed for us to access information on our own, always for our farming as it's our survival.

If only we can have a machine or system that will allow us access to weather information.

Participants did not have any ideas about what such a system might look like but believed that some kind of information system or machine that they could relate to, considering their limited formal education, could be made available to them and that would make their farming easier, informed and productive.

Chapter 5: DISCUSSION

5.1 Introduction

The focus of this chapter is the interpretation and discussion of the results of the study and to bring the findings into conversation with previous studies and/or literature generally. The discussion follows the structure of the previous chapter in terms of being organized according to the thematized presentation of findings.

5.2 Demographics and involvement in farming

The study found that only one of the participants was below 40 years of age, the rest were over 40 years. This is further corroborated by the observation of the researcher in wider interactions of farmers in Swayimane and during information sessions beyond the small sample that were interviewed for the study. This age range suggests that farmers in Swayimane were generally likely to be middle-aged and that there is very limited major participation by the younger population besides assisting their parents. Agriculture in Africa has been shown to be of little attraction to young people who would not deliberately be involved in it and would leave rural areas or dependence on farming when an opportunity presents itself (Tiffen, 2003; White, 2012). Sumberg *et al.* (2012), in their examination of the relationship between young people and agriculture challenges in Africa, demonstrate that while there is a shortage of evidence for the broad range of issues they examined, there is a general linking of factors such as ongoing rural poverty, ageing farming population, rural to urban migration, high levels of unemployment and low agricultural outputs with the non-participation of young people in agriculture in Africa. Asciutti *et al.* (2016) further observed that research evidence is not very clear across Africa on whether rural young people are rejecting on agriculture. Asciutti *et al.* (2016)'s review of studies on the subject showed that the evidence is not clear whether young people are increasingly turning away from agriculture, although some studies suggest this to be the case. They argue that because Africa's rural population is consistently growing, the 'absolute' percentage of rural young people who depend on crop or livestock farming is on the increase, despite declines in some areas of the involvement of young people in agriculture (Asciutti *et al.,* 2016:3). Arguably, the challenges posed by climate change and variability is capable of making agriculture even less attractive to the rural young people who may prefer to pursue other options rather than go through the challenges they saw their parents going through. A study of rural households in 22 countries showed that farming is the preferred occupation for most African households provided that agro-climatic conditions remain favourable – irrespective of integration into, or distance from, urban areas (Davis *et al.,* 2017).

The minimum time of involvement in farming among participants was found to be 15 years, and most had lived their lives farming in Swayimane. Farming was also all they did, it was their primary source of livelihood and resource for caring for their families, some of which were found to be relatively large. This means that their stakes in farming are very high, and most of them also had large or multiple fields in Swayimane. This also means that any problems with yields and other challenges posed by climate change, weather fluctuations and variability very likely have a significant impact on the farmers. Thus, not only would their crops and livestock be affected, several other aspects of their lives and those of their dependents would be affected as well since agriculture was their primary means of livelihood. Nelson *et al.* (2009) observed that in 2005 alone, about 2.5 billion economically active people in developing countries depended on agriculture as a source of livelihood, and that by 2009, 75% of the world's poor lived in rural areas and depended on agriculture to some extent. Nelson *et al.* (2009) further observed that climate change is set to increasingly make life more difficult for these populations because of the ways it will affect yield of crops that are most valued and that projected milestones in other developmental areas would be eliminated or diminished by the impact of climate change on agriculture. Additionally, while the prices of crops that are considered most important would rise without the impact of climate change, this rise will be accentuated by climate change (Nelson *et al.,* 2009). According to Iheke and Agodike (2016) both agriculture and the institutional and social structures that support them are affected by climate change, and the result will be manifested in various aspects of life other than agriculture.

5.3 Challenges and the impact of weather

Farmers, especially in rural areas experience different types of challenge. Some of these challenges are unique to their level of agricultural involvement while others relate to broader agricultural issues. Some of the commonly highlighted challenges include growing technology divide between poor rural farmers and large-scale business farmers, health issues such as HIV and AIDS, population growth in Africa, rising food prices, poor agricultural policies, challenges relating to input and output markets, climate change and variability; and in South Africa, the use of agricultural land for the production of biofuels, land redistribution issues, and the disparity in agricultural practices such as the use of conventional versus sustainable agricultural practices (Binswanger-Mkhize, 2009; Middelberg, 2013; von Loeper *et al.,* 2016).

For the interviewed farmers in Swayimane, poor yields were their primary challenge – when their agricultural efforts do not produce desired or expected results in terms of crop output or livestock. This could result in any of the above factors and more. This study found that poor yields constitutes a worrisome loss for farmers especially when they currently say they experience such losses more frequently than they would consider to be normal. Considering that the study participants had been occupied with agriculture for no less than 15 years, they are likely to be able to identify changes in output and emerging patterns as a result of their farming activities. It appears that while they notice the change in their yields, they had continued to farm the same way they always did, without significant changes to their strategies. They had observed weather fluctuations and increasing unpredictability, and all acknowledged that weather affected their farming outputs. It appears that while they realized that the rains did not always fall when they expected or that sunlight and heat did not follow a consistent pattern as they expected, they still continued to practice agriculture using methods that were not proactive or that were responsive to the weather inconsistencies they observed. This is understandable as these farmers were not equipped with knowledge and skills to respond according to weather changes. Participants' knowledge of how precisely weather changes affect their farming is rudimentary. Since many farmers are heavily dependent on farming, this also constitutes a challenge to the livelihoods of the farmers and their dependents, and possibly entire communities. Thus, given the impact of rising climate change and variability on subsistent agriculture, farmers need more than their own intuition to understand these changes, how it affects them and how to adapt for sustainable agriculture.

Previous studies such as Mengistu (2011) and Mertz *et al.* (2009) indicate varying degrees of knowledge, perception and adaptation to climate variability among farmers in Africa. In Ethiopia, a study on the perception of farmers of the trend of climate change and related issues showed that drought was perceived as the primary hazard related to climate change which occurs frequently and affected their livelihoods (Mengistu, 2011). The study further showed that the absence of modern early warning systems, lack of flexibility among farmers in terms of their cropping calendar and their narrow choices with regards to varying their crops contributed immensely to their vulnerability to climate variability (Mengistu, 2011).

In corroboration with findings of this study, Mertz *et al.* (2009) indicates that farming households in the Sahel region were aware of the variability in the climate and were able to identify wind and excess rainfall as the major climate change factors. Farmers in the study were able to attribute challenges such as deteriorating livestock health and poor crop yields to climate change, especially wind. However, they had to be asked questions within the context of climate before they invoked climate narratives, otherwise farming household challenges were associated with economic, social and political factors rather than climatic factors (Mertz *et al.,* 2009).

5.4 Impact of weather information and change on farming decisions

This study confirms the crucial role that information can play in making a positive impact on the lives of farmers. The study shows that increased access to information increases the consciousness about weather conditions and is likely to impact decision-making among farmers. The farmers in the present study desired good outputs and sustainable agricultural practices. They want to be successful as farming is their source of livelihood. Thus, it could be argued that given the challenges they experienced, they were likely to appreciate any type of information that highlights on their challenges and offers them hope for better yields in future. Thus, even though the information sessions organized for this research were few and infrequent, and the amount of information that could be transmitted was limited, they still found these sessions and other prior information relating to the AWS to be helpful and declared that this affected their planting decisions and planning on the preservation of livestock. The study shows that prior to the installation of the AWS at Swayimane, they had made decisions primarily based on seasons – following what they traditionally planted in winter and summer. However, the ability to think about weather patterns and fluctuations both in the long and short terms was empowering and helpful as they could begin to think in terms of forecast of potential yield given the weather patterns and predictions and to act accordingly. In terms of which type of information was most helpful to them, the farmers did not specify, but they found that the information they received about weather generally was helpful. This could be because they were given basic information and they had not known much to be able to discriminate between the more valuable or relevant information and other types of weather information. Thus, agrometeorological information and access to such information is empowering and could substantially contribute to sustainable local agriculture. Many studies have shown the importance of such information to farmers (Batte *et al.,* 1990; McNew *et al.,* 1991; Fafchamps & Minten, 2012; Mase & Prokopy, 2014). Stone and Meinke (2006) highlight the importance of meteorological and climate information for decision-making among farmers. However, the authors note that different cases have shown that such information need to be tailored to farmers' needs as some information may not be sustainable for certain decisions (Stone & Meinke, 2006).

5.5 Access to weather information and assessment of information meetings

Participants associated the likelihood of success of the URP/UKZN AWS project at Swayimane with their ability to regularly access timely and relevant information. Thus, the aim would be defeated, they believed, unless they are able to access weather information on a regular basis. Their primary concern with regards to the information sessions implemented for this research was that the type of weather information shared with them during these sessions was limited to such sessions and would not be ongoing. While the weather information from the AWS is regularly updated online and displayed on the TV screen installed in their community's high school, farmers did not consider this to be accessible to them, at least, not in the clear and relatable manner they received it during the information sessions. Farmers indicated a preference to continue have such sessions. Additionally, they expressed a desire to know exactly how and when they could access such information on a daily basis and to improve their own knowledge of weather variability and their ability to predict and make informed decisions about their farming activities. This finding agrees with Stone and Meinke (2006) who argue that relevant information must not only be disseminated to farmers but must be tailored to their needs and that a participatory approach is most effective. This is an approach which gives farmers ownership of the processes associated with the development and production of climate and weather information, and promotes the linking of weather information to farm decisions, and can be used during discussion groups for farmers (Stone & Meinke, 2006).

Generally, the information sessions received positive assessment from the participating farmers, with the highlighted limitation being that it was dependent on the researcher arranging a meeting with them, visiting them and using an interpreter. Otherwise, they found the sessions to be clear and they found the opportunity to interact and ask questions to be very helpful. Yet, while they would like to have such information sessions more frequently, they would also like to have a way to access such information directly on their own. Thus, while these sessions were a good strategy, they also created anxieties among farmers. This is because the information they received left them with an appetite for more information and for better and more consistent access, but also left them uncertain about how they could independently access more relevant information. This would require a careful consideration of systems and strategies that are accessible to such farmers. The researcher is aware of the goal of disseminating such information in future through such avenues as mobile phones and radio, as this will be of immense benefit for the farmers, and the strategy of enabling students at Swayimane High School to understand the AWS system, its function and the information it generates and in turn relate these to their families and other community members. The method of disseminating agrometeorological information to farmers is a crucial question in literature, and studies have highlighted the use of the internet, radio and mobile phones among other methods (Percy, 2013; Kgakatsi & Rautenbach, 2014). Part of the emphasis is the need for systems that allow for accurate and timely information. Others have shown that in addition to radio and mobile phones, dissemination organized around interpersonal and group communication and interaction with farmers has proven to be very effective and comprehensive. Mwesigwa and Omukuti (2013) as well as Nderitu and Ayamga (2013) report on such strategies which involved extension workers, project coordinators, farmers and community leaders. These stakeholders, together, discuss and evaluate previous seasons, weather forecasts for the forthcoming season – augmenting scientific and traditional forecasts, use of manure, planting time, crop choices, among other things. The findings of the present study confirm the importance of such interactive strategies in bridging the gap between the formats and methods of presenting scientific weather and climatic information and the ability of farmers to access, interpret and utilize such information to maximize productivity.

5.6 Conclusions

Based on the results of the study, this chapter has demonstrated that agrometeorological information is not only essential to farmers but has the potential to significantly transforming their farming decisions and practices. However, such information needs to be relevant, accessible and intelligible to be useful. In order to achieve this, the study shows that it is not enough to simply transmit such information through the internet, mobile phones and radio, but that strategies that incorporate physical meetings and dialogue can be very effective. This is particularly important for farmers who are not educated. It is also important in helping farmers to better understand the nature and usefulness of the information they receive, and in developing their general understanding of such information and the changing climatic conditions in which they live.

Chapter 6: CONCLUSION AND RECOMMENDATIONS

6.1 Overview

Of all human activities, agriculture is arguably the most dependent on weather and climate irrespective of the agrotechnological advances the world has seen (WMO, 2012). Thus, a key determinant of agricultural successes and sustainable food production is weather and climatic conditions. This study has highlighted the abundance of indicators that climatic conditions are deteriorating globally, and this is particularly felt very harshly in Africa, especially in the many ways it threatens sustainable food production and agriculture including subsistent farmers and rural dwellers. Rapid increase in maximum air temperature extremes, and in the intensity of rainfall and dry spell durations are some of the observed impacts in South Africa (DEA, undated). It is based on this premise and background that this study was conducted in the rural Swayimane community, in uMshwathi Municipality, KwaZulu-Natal.

Literature generally shows that there is a growing consciousness of climate change and its impact on agriculture, and that academics, civil society organizations and the public sector are involved, in varying degrees, in efforts to find lasting solutions to sustainable agriculture, given these challenges. The literature also shows that several advances have been made in Africa and elsewhere in terms of the development of relevant technologies and systems to manage vulnerability to climate change. However, there are still myriads of challenges in this regard including the fact that many rural and small-scale farmers are unable to take advantage of existing models and tools to manage the adverse effects of climate variability on sustainable agriculture. This includes benefiting from agrometeorological information in a timely, meaningful and effective manner.

The overall aim of the study was to understand how weather information collected through the AWS installed at Swayimane High School as part of the UKZN and the uMgungundlovu District Municipality's URP project, and disseminated through the AIM web-based system and on-screen at Swayimane High School, enhances the resilience of farmers to climate change and increases sustainable food production. Particularly, the study sought to offer farmers the opportunity to evaluate the effectiveness of the weather information provided to them and the methods used to share such information with them. Thus, the researcher specifically aimed to collect weather information from the AIM system and share it directly with farmers, to interact with farmers on such information and its implication for their farming activities, and to evaluate their response to the information received and its usefulness to them. Specifically, the study sought to address objectives which were:

- To collate and disseminate AIM system's weather information to farmers in Swayimane
- To understand the weather information received by farmers and its implications on their farming decisions and practices.

The study applied a qualitative research approach which included information meetings with farmers in Swayimane and interviews with some of the farmers who participated in such meetings. The data collected were thematically analysed and the results presented and discussed.

Some of the key findings are that: farmers in Swayimane belong to the aging generation and have farmed for a minimum of 15 years. There does not appear to be a significant involvement of young people in farming in the community. For the farmers, poor crop yields and livestock were the primary challenge they experienced as their agricultural activities did not always produce the desired or expected results. The study also showed that increased access to agrometeorological information also increases the chances for better decision-making and consequently better outputs. The general assessment of the information sessions and the dialogical group method of disseminating weather information to farmers was positive, and the farmers expressed a desire for continuous and consistent access to weather information in ways they can interpret directly. They believed that the methodology enabled them to learn and to better understand many issues. They also believed that unmediated access to weather information would be of great value to them.

6.2 Reconciling the findings with the objectives of the study

This study has taken all necessary steps to meet each of the objectives of the study despite the limitations encountered in the process. A brief summary of how the objectives were met is provided:

6.2.1 To collate and disseminate AIM system's weather information to farmers in Swayimane

As detailed in Chapter 3, the researcher collected weather information from the website where it is streamed as well as other relevant weather information and information about the AWS, among other things. These were shared with farmers during information sessions organized by the researcher. Farmers had the opportunity to interact with the researcher and to ask questions about the information they were given and other problems and uncertainties. The sessions were held with the assistance of an interpreter who also conducted a study in the same research area and has been involved in the URP/UKZN project.

6.2.2 To understand the weather information received by farmers and its implications on their farming decisions and practices.

While the initially envisioned interaction with farmers was more long-term and not confined to group meetings, the primary type of interaction that occurred was during the information sessions. The farmers confirmed that these sessions enabled them to deepen their knowledge and awareness of climate change and variability and the impact it has on their farming activities and lives. They left the sessions feeling more equipped but also yearning for more of such information on a regular basis as they were now more appreciative of the value of agrometeorological information.

The researcher evaluated farmers' responses, and the farmers also provided their own assessment of the strategies used to provide them with information. These were detailed in Chapter 4. Farmers reported that the information they received was useful and guided them in making decisions about what they planted, although the information shared with them was basic. They also found the meetings to be helpful in providing clarity and better understanding of weather and climate related issues.

6.3 Contribution to knowledge

The main contribution of this study is in the interactive approach it adopted to both disseminate and evaluate the agrometeorological information with farmers. The study made the farmers a part of the research process. Thus, even though it was a small-scale study, it highlights the potential for achieving more impactful outcomes when research and intervention strategies are carried out in and with the targeted population. It shows that dialogical approaches can be beneficial to the mitigation of the adverse effects of climate change through physical interaction with local farmers. The study also highlighted the difficulty in communicating weather information to Swayimane farmers. While the URP project is ground-breaking, farmers are yet to feel fully involved in it and to take advantage of its benefits. This study has highlighted some of the issues that need to be taken into consideration as the project develops and attempts to achieve its objectives.

6.6 Conclusion

Climate change and variability remains a critical experience of our daily reality today, and from all indications, the situation could get worse. This poses an immense threat to the planet and to life in different ways. The study has highlighted the fact that farmers in rural communities are among the most affected by the increasing agroclimatic inconsistencies, which threaten to heighten other problems such as poverty. Reliance on farming was affirmed by quotes from farmers who indicated that farming defined their entire livelihoods, and adverse climatic conditions have been negatively impacting on their yields. The study found that with concerted intervention, the impact on farmers can be minimized and managed in ways that allow for sustainable agriculture. Farmers were found to be making climate change-focused decisions which will enhance their yield's resistance to adverse climate. However, findings also showed that technological interventions such as the AIM system are compromised if they do not involve close interaction with farmers in targeted communities in order to include them in the process and enable them to understand and maximize the mutual benefits realised. Hence, it can be seen that without readily available accurate weather information to farmers, farming yield especially in poor communities will continue to decline as adverse climatic conditions persist.

6.5 Recommendations

- Stakeholders involved in the development of the climate change intervention in Swayimane should explore possible ways of making weather information directly accessible to farmers so that they would not have to wait for others to provide them with such information. These may explore more technologies as well as repurposing certain media channels such as radio sessions, or SMS in order not to limit such information to smartphone users only.
- Weather information in Swayimane, if possible, should be made interactive and easily intelligible to make access easier for farmer. It could also be translated and displayed in isiZulu and/or include voice-overs in the local language, so that older farmers who are unable to read can still benefit from the system.
- The project at Swayimane will immensely benefit from a more regular direct interaction with the farmers for question-and-answers, information sessions, and other interactive contacts where farmers develop their knowledge and skills, and the project gains more insight into the community where it is located and executed.

6.4 Limitations of the study and challenges experienced

Some of the limitations and challenges experienced during this study include the following:

- The fact that interview data were collected from a small sample means that generalizability is limited. However, the study was designed in such a way that the sample interviews were one component of a broader research process that included information meetings and interaction with farmers within that space. Language was another limitation in terms of organizing interviews and meetings with farmers because the researcher is not fluent in isiZulu, which is the local language of the research site, and the farmers were not fluent in English. Thus, the researcher needed to interact with the help of an interpreter, which was not always easy to organize. This factor contributed to limited volume of content available for data analysis. Thus, the researcher was unable to collect as detailed information as was planned. Reponses were often brief, and further probing did not yield the detailed information for which the researcher had hoped.

- The study was initially planned with the expectation that the planned dissemination using mobile phones and other methods would be implemented. However, since this did not happen as expected, the researcher had to improvise to find ways of bringing relevant meteorological information directly to the farmers in order to proceed with the study. Thus, this study was not able to assess more than one method of disseminating agrometeorological information in order to offer a comparative perspective on which ones are more effective.

6.5 Recommendations for future research

- Future studies may explore a larger population using the methods applied in this study, that is, a combination of information meetings, interviews and observation. This will provide further information on the usefulness, limitations and advantages of such methodologies for understanding rural farmers' interaction with climate change related information and technology. It will also enrich our understanding of more suitable ways to relate to farmers in such contexts based on a larger sample size and possibly a longer period of study and interaction with farmers.
- It will also be interesting to understand whether, to what extent and how, younger rural population in such places as Swayimane who have access to agrometeorological information at school are able to communicate such information to their parents and other farmers in their communities. The UKZN-URP project at Swayimane High School is yet to fully explore this indirect means of reaching farmers and its effectiveness in achieving the overall goals of the project. Future studies could explore this issue.

REFERENCES

Ababale, S., 2013. Rainfall recording: a community decision making tool in Niger. *Joto Africa, Arid LandsInformation Network,* Nairobi, Kenya 1(12), pp. 1-20.

Adejuwon, J.O., 2006. Food crop production in Nigeria. II:. pPotential effects of climate change. *Climate Research*, 32(3), pp. 229–245.

Amegnaglo, C. 2015. Are Agrometeorological forecasts useful or harmful for smallholders in Africa: what does the literature say? *6th Global Development Conference: Agriculture for Sustainable Growth- Challenges and Opportunities for a New Green Revolution*, Casablanca, pp. 1–19.

Asciutti, E., Pont, A., & Sumberg, J. 2016. Young people and agriculture in Africa a review of research evidence and EU documentation. *Institute of Development Studies, Brighton, UK,* 2016(82), pp. 1-68.

Asfaw, S., McCarthy, N., Lipper, L., Arslan, A., Cattaneo, A., & Kachulu, M. 2014. Climate variability, adaptation strategies and food security in Malawi, *ESA Working Paper No. 14-08, Rome, Food and Agriculture Organisation,* pp. 1-35.

Batte, M.T., Jones, E., & Schnitkey, G. D. 1990. Farm information use: an analysis of production and weather information for Midwestern cash grain farmers. *Journal of Production Agriculture,* 3(1), 76–83.

Bengtsson, M. 2016. How to plan and perform a qualitative study using content analysis. *Nursing Plus Open*, 2(1), 8–14.

Bernard, H. R. 2017. Research methods in anthropology: qQuantitative and qualitative approaches. *4th ed. Oxford, UK: Rowman and Littlefield Publishers.*

Binswanger-Mkhize, H.P. 2009. Challenges and opportunities for African agriculture and food security. *Expert Meeting on How to feed the World in 2050, Food and Agriculture Organization,* pp. 1-54.

Brannen, J. 2017. Mixing methods: Qualitative and quantitative research. *1st ed. London: Routledge.*

Brinkmann, S. & Kvale, S. 2008. Ethics in qualitative psychological research. *The Sage handbook of qualitative research in psychology*, 24(2), 263–279.

Cahir, J. 2019. Weather forecasting: Methods, Importance, & History [online]. *Encyclopedia Britannica*. Available from: https://www.britannica.com/science/weather-forecasting [Accessed 26 Aug 2019].

Climate Council of Australia. 2016. The hottest year on record (again). Available from climatecouncil.org.au/uploads/d8ed2731739da328fe6149ca1e17f9a9.pdf [climatecouncil.org.au/uploads/d8ed2731739da328fe6149ca1e17f9a9.pdf [Accessed 29 Aug 2019].

CNA Military Advisory Board. 2014. National security and the accelerating risks of climate change. *CNA Corporation*, pp. 1-45.

Davis, B., Di Giuseppe, S., & Zezza, A. 2017. Are African households (not) leaving agriculture? Patterns of households' income sources in rural Sub-Saharan Africa. *Food Policy*, 67, pp. 153–174.

Department of Environmental AffairsDEA, 2013. Department of Environmental Affairs: Annual report 2012/2013. Pretoria: Department of Environmental Affairs, South Africa.

Department of Environmental AffairsDEA, n.d. National Climate Change Response: White Paper. Pretoria, South Africa: Department of Environmental Affairs.

Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.-F., & Schmidhuber, J. 2007. Food, fibre and forest products. *Climate Change*, pp. 273–313.

Elmusharaf, K. 2012. Qualitative sampling techniques, training course in sexual and reproductive health research, University of Medical Science and Technology, Geneva

Fafchamps, M. & Minten, B. 2012. Impact of SMS-based agricultural information on Indian farmers. *The World Bank Economic Review*, 26(3), 383–414.

Gandure, S., Walker, S., & Botha, J.J. 2013. Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. *Environmental Development*, 5, 39–53.

Gbetibouo, G.A. 2009. Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. *Intl Food Policy Research Institute, IFPRI Research Brief 15-8,* Washington DC, USA.

Graneheim, U.H., Lindgren, B.M., & Lundman, B. 2017. Methodological challenges in qualitative content analysis: A discussion paper. *Nurse Education Today*, 56, 29–34.

Hansen, J.W., 2002. Realizing the potential benefits of climate prediction to agriculture: issues, approaches, challenges. *Agricultural Systems*, 74(3), 309–330.

Hewitson, B.C., Tadross, M., and Jack, C. 2005. Historical Precipitation Trends over Southern Africa: A Climatology Perspective. *In*: R.E. Schulze, ed. *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation.* Pretoria: Water Research Commission, Pretoria, 319–324.

Iheke, O.R. & Agodike, W.C. 2016. Analysis of factors influencing the adoption of climate change mitigating measures by smallholder farmers in Imo State, Nigeria, *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development,* 16(1), 8.

Ingram, K.T., Roncoli, M.C., & Kirshen, P.H. 2002. Opportunities and constraints for farmers of West Africa to use seasonal precipitation forecasts with Burkina Faso as a case study. *Agricultural Systems*, 74(3), 331–349.

Intasave Africa. 2015. Use and communication of climate information to support uptake of adaptation action in the semi-arid regions of Africa and Asia. *ASSAR Working Papers,* Ottawa, Canada, pp. 1-59.

IPCC, 2014. Climate Change 2014: Synthesis Report. *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva.
Joto Africa. 2011. Women as key players in climate adaptation, *Department for International Development*, Nairobi, Kenya

Kassie, B.T., Hengsdijk, H., Rötter, R., Kahiluoto, H., Asseng, S., & Van Ittersum, M. 2013. Adapting to Climate Variability and Change: Experiences from Cereal-Based Farming in the Central Rift and Kobo Valleys, Ethiopia. *Environmental Management*, 52(5), pp. 1115–1131.

Kgakatsi, I.B. & Rautenbach, C.J. deW. 2014. The contribution of seasonal climate forecasts to the management of agricultural disaster-risk in South Africa. *International Journal of Disaster Risk Reduction*, 8, pp. 100–113.

Khan, S.A., Kumar, S., Hussain, M.Z., & Kalra, N. 2009. Climate Change, Climate Variability and Indian Agriculture: Impacts Vulnerability and Adaptation Strategies. *In*: S.N. Singh, ed. *Climate Change and Crops*. Berlin, Heidelberg: Springer, pp. 19–38.

Liu, J., Fritz, S., Van Wesenbeeck, C.F.A., Fuchs, M., You, L., Obersteiner, M., & Yang, H. 2008. A spatially explicit assessment of current and future hotspots of hunger in Sub-Saharan Africa in the context of global change. *Global and Planetary Change*, 64(3–4), pp. 222–235.

Lwande, O. & Lawrence, M. 2008. Agro-meteorological knowledge management system for small scale farmers. *Strengthening the Role of ICT in Development*, 243.

Maponya, P., & Mpandeli, S. 2012. Climate change and agricultural production in South Africa: impacts and adaptation options, *Journal of Agricultural Science,* 4(10), pp. 48-60.

Mase, A.S. & Prokopy, L.S. 2014. Unrealized potential: A review of perceptions and use of weather and climate information in agricultural decision making. *Weather, Climate, and Society*, 6(1), pp. 47–61.

Matungul, P.M. 2000. Buying patterns for staple foods amongst rural households in KwaZulu-Natal informal constraints perspective in Impendle and Swayimane. *Agrekon*, 39(2), pp. 142–150.

McNew, K.P., Mapp, H.P., Duchon, C.E., Merritt, E.S., McNew, K.P., Mapp, H.P., Duchon, C.E., & Merritt, E.S. 1991. Sources and uses of weather information for agricultural decision makers. *Bulletin of the American Meteorological Society*, 72(4), pp. 491-498.

Mengistu, D.K. 2011. Farmers' perception and knowledge on climate change and their coping strategies to the related hazards: case study from Adiha, central Tigray, Ethiopia. *Agricultural Sciences*, 2(2), pp. 138-145.

Mengistu, M.G., Everson, C.S., Moyo, N.C., Savage, M.J. The validation of the variables (evaporation and soil moisture) in hydrometeorological models, World Research Commission Report No. 2066/1/13, pp. 1-67.

Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. 2009. Farmers' perceptions of c/limate change /and agricultural adaptation strategies in rural Sahel. *Environmental Management*, 43(5), pp. 804–816.

Middelberg, S.L. 2013. Sustainable Agriculture: A rReview of challenges facing the South African agricultural sector. *Journal of Human Ecology*, 42(2), pp. 163–169.

Molnar, J.J. 2010. Climate change and societal response: livelihoods, communities, and the environment. *Rural Sociology*, 75(1), pp. 1–16.

Morton, J.F., 2007. The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the national academy of sciences*, 104(50), pp. 19680–19685.

Mwesigwa, J.B. & Omukuti, J., 2013. Communities benefit from agro-meteorology advice in Kenya. *Joto Afrika: Adapting to climate change in Africa*, 12(3), pp. 3.

Myers, S.S., Smith, M.R., Guth, S., Golden, C.D., Vaitla, B., Mueller, N.D., Dangour, A.D., & Huybers, P. 2017. Climate change and global food systems: potential impacts on food security and undernutrition, *Annual Review of Public Health,* 1(38), pp. 259-277.

Nderitu, J.M. & Ayamga, T., 2013. Making seasonal forecasts usable in Ghana and Kenya iIn climate communication for adaptation. *Joto Africa, Arid Lands Information Network, Nairobi, Kenya, (12)*, pp. 3.

Ndlovu, M. 2019. Impact of drought and extreme air temperature on smallholder farmers in the Swayimane and Msinga rural communities of KwaZulu-Natal, South Africa. *University of KwaZulu-Natal,* Petermaritzburg.

Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., & Batka, M. 2009. Climate change: Impact on agriculture and costs of adaptation. *International Food Policy Research Institute,* Washington DC, USA, pp. 1-30

Nhemachena, C. & Hassan, R., 2007. Micro-level analysis of farmers adaption to climate change in Southern Africa. *International Food Policy Research Institute,* Washington DC, USA, pp. 1-30
NOAA. 2015. Global climate report - Annual 2015 state of the climate National CentersCentres for Environmental Information (NCEI) [online]. Available from: https://www.ncdc.noaa.gov/sotc/global/201513 [Accessed 20 Aug 2019].

NOAA. 2017. Global climate report - Annual 2017 state of the climate National Centers for Environmental Information (NCEI) [online]. Available from: https://www.ncdc.noaa.gov/sotc/global/201713 [Accessed 20 Aug 2019].

O'brien, K., Eriksen, S., Inderberg, T.H., Sygna, L. 2015. Climate change and development Adaptation through transformation, *Nordic Development Fund,* pp. 1-12

Okezie, C.A., Udodirim, U., Okezie, C.R., & Sulaiman, J. 2011. Climate variability and change: perceptions and adaptations in subsistence agriculture. *Indian Journal of Agricultural Research*, 45(4), pp. 275-281.

Orb, A., Eisenhauer, L., & Wynaden, D. 2001. Ethics in qualitative research. *Journal of Nursing Scholarship*, 33(1), pp. 93–96.

Oyekale, A.S. 2015. Access to risk mitigating weather forecasts and changes in farming operations in east and West Africa: evidence from a baseline survey, *Sustainability,* 7(1), pp. 14599-14617.
Percy, F. 2013. Climate communication for adaptation. *Joto Afrika: Adapting to climate change in Africa, 12*, pp. 1.

Roncoli, C., Ingram, K., & Kirshen, P. 2001. The costs and risks of coping with drought: livelihood impacts and farmers responses in Burkina Faso. *Climate Research*, 19(2), pp. 119–132.

Roncoli, C., Ingram, K., & Kirshen, P. 2002. Reading the rains: local knowledge and rainfall forecasting in Burkina Faso. *Society & Natural Resources*, 15(5), pp. 409–427.

Roudier, P., Ducharne, A., & Feyen, L. 2014. Climate change impacts on runoff in West Africa: a review. *Hydrology and Earth System Sciences*, 18, pp. 2789–2801.

Rutherford, M.C., Mucina, L., & Powrie, L.W. 2006. Biomes and bioregions of southern Africa. *The vegetation of South Africa, Lesotho and Swaziland*, 19, pp. 30–51.

Sani, L., Boadi, B.Y., Oladokun, O. & Kalusopa, TO., O., and T., K. 2014. The Generation and Dissemination of Agricultural Information to Farmers in Nigeria: A Review. *IOSR Journal of Agriculture and Veterinary Science*, 7 (2), pp. 102–111.

Schlenker, W. and Lobell, D.B. 2010. Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, 5(1), pp. 1-8.

Selvaraju, R., Gommes, R., & Bernardi, M. 2011. Climate science in support of sustainable agriculture and food security. Climate Research, 47(1), pp. 95–110.

Sharma, G. 2017. Pros and cons of different sampling techniques, *International Journal of Applied Research*, 3(7), pp. 749-752

Silverman, D. 2016. Qualitative research. 4th ed. London, UK: SAGE Publications.

Sivakumar, M.V.K. 2006. Dissemination and communication of agrometeorological information—global perspectives. *Meteorological Applications*, 13(1), pp. 10-30.

Statistics South Africa. 2012. Statistical release (Revised): Census 2011. Pretoria: Statistics South Africa, No. P0301.4.

Stefanski, R., Holden, N., Orlandini, S., Shostak, R., & Zoidze, E. 2010. Application of meteorology to Agriculture. *In*: *WMO Guide to agrometeorological practices*. Geneva: WMO.

Steffen, W. & Fenwick, J. 2016. Climate Council Seasonal Update: Abnormal Autumn 2016.

Stigter, K. 2010. (Changes in) adaptation strategies to climate changes: Monocropping, *Applied Agrometeorology,* Springer, Berlin, Heidelberg, pp 359-362.

Stigter, K., 2010. *Applied Aagrometeorology*. Springer Science & Business Media.

Stigter, K., Winarto, Y.T., Ofori, E., Zuma-Netshiukhwi, G., NanjaD., and Walker, S. 2013. Extension Agrometeorology as the Answer to Stakeholder Realities: Response Farming and the Consequences of Climate Change, *Atmosphere,* 4(1) pp. 237-253.

Stone, R.C. & Meinke, H. 2006. Weather, climate, and farmers: Aan overview. *Meteorological Applications*, 13(1), pp. 7-20.

Sumberg, J., Anyidoho, N.A., Leavy, J., te Lintelo, D.J.H., & Wellard, K. 2012. Introduction: The young people and agriculture 'problem' in Africa. *IDS Bulletin*, 43(6), pp. 1–8.

Tibesigwa, B. & Visser, M. 2015. Small-scale subsistence farming, food security, climate change and adaptation in South Africa: Male-female headed households and urban-rural nexus. *ERSA working paper 527, Economic Research Southern Africa,* Cape Town, pp. 2-32

Tibesigwa, B., Visser, M., & Turpie, J. 2015. The impact of climate change on net revenue and food adequacy of subsistence farming households in South Africa. *Environment and Development Economics*, 20(3), pp. 327–353.

Tiffen, M. 2003. Transition in sub-Saharan Africa: agriculture, urbanization and income growth. *World Development*, 31(8), pp. 1343–1366.

Tshiala, M.F., Olwoch, J.M., Engelbrecht, F.A. 2011. Analysis of temperature trends over Limpopo province, South Africa. *Journal of Geography and Geology*, 3(1), pp. 13-21.

Tubiello, F., Schmidhuber, J., Howden, M., Neofotis, P. G., Park, S., Fernandes, E., & Thapa, D. 2008. Climate change response: Strategies for agriculture: Challenges and opportunities for the 21st century. *Agriculture and Rural Development Discussion Paper 42.* Washington DC: The World Bank.

University of California, 2014. California PestCast: Description. [Online] Available at: http://ipm.ucanr.edu/DISEASE/pestcast_description.html [Accessed 2 March 2020].

USAID, 2012. USAID climate adaptation plan. USAID. Available on https://www.usaid.gov/sites/default/files/documents/1865/Agency%20Climate%20Change%20Adaptation%20Plan%202012.pdf [Accessed 02 Dec 2019]

von Loeper, W., Musango, J., Brent, A., & Drimie, S. 2016. Analysing challenges facing smallholder farmers and conservation agriculture in South Africa: A system dynamics approach. *South African Journal of Economic and Management Sciences*, 19(5), pp. 747–773.

Weiss, A., Van Crowder, L., & Bernardi, M. 2000. Communicating agrometeorological information to farming communities. *Agricultural and fForest Meteorology*, 103(1–2), pp. 185–196.

Werford, A., Moran, D., & Adger, N. 2010. Climate change and agriculture: Impacts, adaptation and mitigation. *Organisation for Economic Cooperation and Development (OECD),* Paris.
White, B. 2012. Agriculture and the generation problem: rural youth, employment and the future of farming. *IDS Bulletin*, 43(6), pp. 9–19.

WMO. 2012. WMO Statement on the Status of the Global Climate in 2011. *World Meteorological Association* Geneva, Switzerland.

APPENDIX 1: ETHICAL CLEARANCE

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

11 September 2017

Mr Adesegun Quam Popoola 216076593
School of Agriculture, Earth and Enviromental Sciences
Pietermaritzburg Campus

Dear Mr Popoola

Protocol reference number: HSS/1023/017M
Project title: Using Agrometeorological data to equip local farmers for sustainable food production in Swayimana, KwaZulu-Natal

Full Approval – Expedited Application

In response to your application received 10 July 2017, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

pp **Dr Shenuka Singh (Chair)**
Humanities & Social Sciences Research Ethics Committee

/pm

cc Supervisor: Prof Mike Savage
cc. Academic Leader Research: Professor Onisimo Mutanga
cc. School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood | Howard College | Medical School | Pietermaritzburg | Westville

APPENDIX 2: INTERVIEW RESPONSES

The following responses are presented per participant, and are in both iSiZulu (interview language) and English (Researcher's translations).

RESPONDENT ONE (OWOKUQALA OPHENDULILE)

IsiZulu

1. Owokuqala ophendulile, Nginezingane ezinthathu. Ngineminyaka eyamashumi amathathu nesishiyagalombili.
2. Ngazalelwa khona la kaSwayimane ngakhulela khona.
3. Sikhule kulinywa la ekhaya, kusukhela siqala isikole emabangeni aphansi.
4. Silima izingadi/amasimi okudla
5. IsimoSezulu esingaqondakali,kwesinye isikhathi uthi usutshalile, lingani, libalele kakhulu.
6. IsimoSezulu sinomthele omkhulu ezithshalweni, ngingasho nje ngithi ezinye ziyasha, ezinye zingatheli, zibole njalonjalo.
7. Lukhina lona ushintsho kancane, ngoba sengiyasibheka kuqala isimo sezulu ngaphambi kokutshala; ngisthshale okufanelene naso bese kuhlume, kukhiqize isivuno nakuba kungokwesikhathi esifishane.
8. Bengicabangela nje ukuthi, ngekwazi ukuthi isebusika angitshale into engavumi. Lana nokungabikho kwamanzi ngengo-bhonthisi, bengisibeka kona emqondweni isimo sezulu kodwa ngingenalwazi olujulil. Bengifunda amafu, ngebhekele imvula.
9. Ukuchazelwa ngokucacele ngesimo sezulu, nobudlelwano, kanye nomthelela esinawo nokulima/okutshala.
10. Ukuthi asizokwazi ukwazi ukuthola ulwazi ngesimo sezulu njalo/nsukuzonke.
11. Ukuthola ukwazi mayelana, nohlobo/wezithshalo ezivumelana nomhlabathi esithshala kuwo.
12. Kusisizile kahulu ukuchazelwa ngumuntu sixoxe, sikwazi nokhubuza imibuzo.
13. Ukuba nendawo lapho sizofakelwa khona umshini wokuzibonela isimo sezulu. Sifundiswe ukusifunda- bese sizithathela izinqimo.

RESPONDENT ONE

1. Respondent 1, a 38 years old single parent with three children.

2. Born in Swayimane and has spent most of my life in Swayimane.

3. Since I was born, in my home we were surviving through farming since my primary schooling.

4. We plant food gardens and vegetable gardens

5. Weather conditions are unpredictable. E.g. sometimes after planting no rain, only extreme heat experienced.

6. Weather conditions have big impact on our farming, as some plants wither and die, no produce obtained

7. There is a slight change, since now before putting seed on the ground I first consider weather condition and plant what will be favoured by it.

8. I was working on assumption according to seasons, that if its winter I plant seeds that do not need lot of water like sugar beans, since I had no detailed knowledge of weather to carefully consider it.

9. Being informed of weather condition, the relationship it has with farming and its impact on farming.

10. The information I feel is still of a disadvantage is that we cannot have access to weather condition knowledge always available.

11. We still need the information about type of seeds suitable for our soil along with weather condition as it may be related to produce.

12. Method of information dissemination was much easier as it was direct from the source and we were able to ask questions for clarity.

13 .It will be much recommended that we can have access to an installed weather system in our area to access weather information on continuous basis as farmers.

OWESIBILI OPHENDULILE

1. Owesibili ophendulile: Ngineminyaka ewu 45years. Ngihlala endaweni yakwaSwayimana. Nginezingane ezine.
2. Ngihlale endaweni yase Swayimane isikhathi esingaphezulu kwamashumi amathathu.
3. Iminyaka eyishumi nanhlanu ngaqala ukulima.
4. Amasimu amakhulu impela, Kanye nenfuyo, izinkomo nezimbuzi.
5. Iyafa imfuyo yami engikuqaphe, layo ayandi kahle ngize ngiyidayise.
6. Kungenzeka ngempela isimo sezulu sinawo umthelela kulukhu.
7. Kukhona ushintsho olubekhona emva kokwaziswa ngesimo sezulu - Nginokuthi ngikhethe izitshalo ezihambisana nesimo sezulu, nokugcina imfuyo ngendlele efanele,nokudla kwayo kuqoqwe kugcinwe kahle zingafi izinkomo ngenxa yesomiso
8. Bengingasiqapheli isimo sezulu,ngaphambili bengitshala noma yini, ngifuye ngingabuki ukuthi ngisho nokudla kwemfuyo kuhambisana nesimo sezulu.
9. Ukwaziswa ngokusebenza kwesimo sezulu ngokukhuluma sibhekene,ngibenethuba lokubuza imibuzo
10. Ukuthi saziswe ukuthi asizokwazi ukuthola ulwazi njalonjalo.
11. Kungasisiza ukuba saziswe nangolwazi lasingathola khona ngesimo sezulu njalo.
12. Iyasisiza kakhulu indlela esifundiswe ngayo ngoba besikwazi nokubuza lasingakhanyiselekile khona
13. Uma singafakelwa into esizozifundela khona isimo sezulu nsukuzonke.

RESPONDENT 2.

1. A 45years old, living in Swayimane community. I have four children.
2. I have been in Swayimana for more than 30years
3. For more than 15 years I have been farming.
4. I plant fields of mealies, beans, cocoyam, sweet potatoes etc. and keep stock, like cattle and goats.
5. My stock dies and it is not thriving well, I am sometimes forced to sell it.
6. It may happen weather condition has an impact to this
7. There is a change after gaining knowledge about weather conditions and relationship it has with farming. I choose what to plant and caring for my stock accordingly and keep stock feeds to avoid hunger during drought.
8. I was not taking consideration of weather conditions, as a results I was planting anything, even animal feeds was not planned according to weather.
9. Being informed about weather conditions on direct or on one on one basis and had opportunity to ask questions.
10. What seems a challenge still is that the weather information will still remain inaccessible, after this informative session.
11. It can help us to be informed as to where can we get the weather information always.
12. It helped a lot the method the information was given to us as it was direct from source and opportunity was afforded for us to ask questions.
13. If we can have a weather information system installed for us to access information on our own, always for our farming as its our survival.

OWESTHATHU OPHENDULILE

1. Owesithathu ophendulile: Ngingowokuzalwa kaSwayimane, ngiganiwe nginamakhosikazi amabili,nezingane eziyishumi nambili.Ngineminyaka eyamashumi amahlanu nambili.
2. Ngingowokuzalwa khona la kwaSwayimane.
3. Ngaphezu kwamashumi amabili ngaqala ukulima.
4. Ngilima amasimu amaningana, kwazise nginemizi emibili eyehlukene.
5. Ngingathi iminyaka kayifani,ngiyazuza komunye komunye nbimoshakale
6. Izulu linawo umthelela ekulimeni
7. Uyabonakala kakhulu umehluko,ngoba sengitshala okufanele ngesikhathi esihambelana nesimo sezulu,azisamoshakali izitshalo zami njengakuqala
8. Bengingaze ngasiqaphela isimo sezulu, bengitshala nje noma ikanjani ngoba kufanele ngondle umndeni wami.
9. Ukucophelela ukutshala okufanele okufanele ngesikhathi esifanelene nesimo sezulu
10. Kwakungesilona usizo ukubhekwa kwesimo sezulu kanye osukwini, ngoba singashintsha noma inini.
11. Yebo, Kumele sazi ukuthi singaluthola kanjani futhi laphi lolulwazi esikhathini esilandelayo.
12. Indlela oluziswe ngayo ulwazi luyancomeka ngoba besixoxa.
13. Yebo, Uma lingafinyeleleka ulwazi lapha endaweni esihlala kuyo, singalindi ukuthi kuyoze kufike omunye umuntu.

RESPONDENT 3

1. Born and bred at Swayimane, married to two wives with twelve children, and he's 52 years old.
2. I have been at Swayimane all my life.
3. I have been farming for more than 20years.
4. I am farming quite a few fields as I have two separate family homes.
5. It is not the same challenges, they vary from benefiting good crop produce to sometimes none.
6. Yes weather has impact on my farming.
7. There is a change since the weather information received as now my farming is based on weather and crops are selected accordingly to weather favourability than before.
8. No, weather conditions were not taken into consideration, I was just planting anyhow with the aim to care for my family.
9. To consider weather conditions before embarking on farming and type of seeds suitable.
10. It was not helpful that weather condition is checked once on a day, when it can change at anytime
11. Yes, to know how and where we can access this information on daily basis in the future.
12. The method of dissemination was useful as we were discussing directly.
13. Yes, suggest if this weather information can be accessed in our area without waiting for anyone to come once in a while.

OWESINE OPHENDULILE

1. Owesine ophendulile: Ngihlala endaweni yakwaSwayimane, ngafika kulendawo ngizoqala isikole emabangeni aphansi.Ngineminyaka eyamashumi amahlanu, nginezingane ezinhlanu.
2. Ngaphezu kwamashumi amane nanhlanu ngililungu lomphakathi.
3. Ngaphezu kwamashumi amabili nanhlanu ngaqala ukuba ngumlimi
4. Nginamasimu ayisithupha engitshala kuwo umbila, ubhatata, amadumbe,ubhontshisi,njalonjalo...
5. Ubuye ungavumi umbila ungatheli kahle,iminyaka kayifani.
6. Nginngathi izulu ukuthi liyana,alini kunawo umthelela.
7. Kukhona ushintsho, ngokuqaphela isimo sezulu,ngingathi sengiyakwazi ukuhlela izitshalo ngendlela ,ehambisana nokuzothela imiphumela ejabulisayo.
8. Bekuyinto ebengingayinaki leyo bengitshala nje ngoba kufanele
9. Ukwaziswa ngobudlelwano phakathi kokutshala nesimo sezulu kungisizile kakhulu.
10. Ukwazi ukuthi ngeke siluthole lolulwazi njalo
11. Ukuthi singafinyelela kanjani ekutholeni lolulwazi njalo.
12. Ibe lusizo kakhulunjengoba lulethwe kuthina lolulwazi sixoxa, sibuza nemibuzo. Uma singakwazi ukufakelwa umshini ,osifundisa ngesimo sezulu.

RESPONDENT 4

1. Respondent 4 lives in Swayimane since starting primary level schooling, 50years old with five children.
2. A Swayimane community member for more than 45 years.
3. I have been farming for more than 25 years.
4. I have six fields that I farm on, where I plant mealies, sweet potato, cocoyam, beans etc.
5. Challenges experienced are that, sometimes, harvest of mealies is not much, but differs with years.
6. Yes weather has impact as sometimes one thinks its going to rain, it does not.
7. There is a change as I now note the weather conditions than plan seeds to plant and have pleasing harvest.
8. No I just planted my seeds as it was necessary.
9. To be informed of weather conditions and relationship it has with farming has helped me.
10. It is not helpful to know that this weather information cannot be accessed always.
11. Yes, how can we access weather information on a continuous basis.
12. It was very helpful as the information was brought directly to us and questions could be asked.
13. If only we can have a machine or system that will allow us access to weather information.

OWESIHLANU OPHENDULILE

1. Owesihlanu ophendulile: Ongowokudabuka lapha kwa Swayimane, ngiphila ngokulima,ngineminyaka eyamashumi amane nesikhombisa ,nginabantwana abahlanu.
2. Kusukela ekuzalweni kwami ngililungu lalomphakathi.
1. 3, Ngiphila ngakho ukulima.
3. Ngilima labodukathole bamasimu kababa.
4. Inkinga ukuthu kwesinye isikhathi umuntu usebenzela ize ,kungabi nasivuno esithokozisayo
5. Isimo sezulu ngingasho ukuthi sinawo umthelela
6. Lukhona lona ushintsho, ngoba manje ngiyalibuka izulu ngifunde ukuthi lizona,noma cha,umoya nokuduma kungenzeka, bese ngihlela engizokufaka emhlabathini.
7. Bengingaze ngiqaphele isimo sezulu, bengivane ngitshale ngokucabangela
8. Ukuthi kufanele ngibheke isimo sezulu phambi kwesinqumo sokutshala.
9. Ukuthi lolulwazi aluzotholakala ngalendlela njalo
10. Ungasazi kanjani isimo sezulu ukuthi sizoshintsha nini.isikhathi esingakanani phambi kokuba utshale
11. Isenzele izinto lula kakhulu ukuba sikhulumisane.
12. Ukuba nendlela ezohlala ikhona yokuzitholela ulwazi ngesimo sezulu.

RESPONDENT 5.

1. 47years old with five children, born in Swayimane, I live off farming.
2. I lived all my life as a member of Swayimane community.
3. As I have alluded to the fact that farming is my life
4. I farm a very big inherited family land.
5. The challenge is that sometimes our work /farming is in vain or yield no results.
6. Yes I can say that weather conditions play a role.
7. There is a change since I now study the weather whether it will rain or not or even suspicious of storms, than plan what to put in the soil.
8. No I did not take weather condition into consideration, I just based my farming in assumptions of the weather
9. Is that I must consider weather condition before planting.
10. It is that this information will not be available always as we got it.
11. Yes ,it is that how can one know as to when the weather condition will change and for how long will it remain the same way before planting.
12. The method of information dissemination made things easier as information was shared direct to us.
13. Yes, it is to have a way which will make weather information accessible to us

OWESITHUPHA OPHENDULILE

1. Owesithupha ophendulile: Ngingumzali onezingane eziyisithupha.Ngineminyaka eyamashumi ayisihlanu nanhlanu.
2. Ngiyilunga lomphakathi wakwaSwayimane.
3. Ngaphezu kweminyaka eyamashumi amabili ngaba umlimi.
4. Ngilima amasimu obaba ngondle umndeni wami.
5. Izivuno aziphumeleli njalo, komunye unyaka kuhamba kahle ,komunye kungavumi kahle'
6. Sinako ukuba nomthelela isimo sezulu
7. Kungilethele ushintsho ukufundiswa ngokusebenza ngesimo sezulu.
8. 8 .Bengingaze nganaka ukuba ngibheke isimo sezulu ngaphambi kokutshala.
9. Ukuthi kufanele ngazi ngesimo sezulu ngaphambi kokuhlela ukuthi yini engiyifaka emhlabathini.
10. Ukubheka isimo sezulu okwamanje,bese ungasakwazi ukuphinde wazi ngaso futhi kungabi into eqhubekayo.
11. Ukuthi singafinyelela kanjani ekubeni sazi njalnjalo ngesimo sezulu
12. Ukuba sithole ukulethelwa ulwazi mathupha sikhulumisane
13. Ukuba sikwazi ukuzitholela ngesimo sezulu njalonjalo.

RESPONDENT 6

1. A 55 years old, a single parent with six children.
2. I am a member of Swayimane community.
3. I have been farming for more than 20years
4. I farm fields inherited from my father to carter for my children.
5. The main challenge is that harvest is not always good.
6. Yes weather conditions have an impact on farming.
7. Yes there is a change in the way I have been farming since the weather information received and now
8. No, I never took note of weather conditions prior planting.
9. I found it useful that I need to understand weather conditions before planning what to plant on the soil.
10. It is to know weather information and never to access it again for future reference.
11. Yes to know how else we can access the weather information on continuous basis.
12. The method was direct from source in a communication basis.
13. Yes, it will be better for us to access weather information on our own on a continuous basis.