The use of traditional weather forecasting by agro-pastoralists of different social groups in Bobirwa sub-district, Botswana

By

Bonolo Mosime

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Supervisors: Dr Dian Spear and Dr Admire Nyamwanza

Declaration

I, *Bonolo Mosime*, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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Dedication

I dedicate my thesis to my grandparents, John Phalaagae Dintwe and Matlhodi Dintwe, who have always been passionate about agriculture. Through their hard work in agro-pastoralism, I aspire to understand their passion through their lenses. With your words of wisdom and encouragement you have taught me to be inquisitive.

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Abstract

Agro-pastoralists of Bobirwa sub-district depend mainly on rain-fed agriculture as a source of their livelihood. However, this agro-pastoralism is affected by climatic variability. Advanced warning of upcoming weather information is, therefore, important in informing farming decisions. Traditional weather forecasting is often a major planning tool used to inform agro-pastoralists' decision making and has been handed from one generation to another. For instance, local knowledge indicators are used to determine onset of rainfall and quality of the rainfall expected. However, there are numerous factors that may have affected the effective use of and dependence on traditional weather forecasting over the years. For this reason, it is critical to examine the current state and use of traditional weather forecasting among the agro-pastoralists. This thesis describes the traditional weather forecasting that agro-pastoralists in Bobirwa sub-district Botswana hold and use in planning for agricultural activities to cope with climate variability. It also examines changes that have been observed in the use of traditional weather forecasting over time. By exploring the knowledge used to generate early warning systems and coping strategies to climate variability of agro-pastoralists, we examine underlying vulnerabilities and resilience possibilities. Data was collected through purposively selecting a total of 101 agro-pastoralists who were further stratified by age and gender. The following qualitative techniques were used in data collection: semi-structured interviews (54 interviewees constituting 37 forecasters and 17 non-forecasters), focus group discussions (47 participants consisting of between 4 and 12 participants), and key informant interviews (11 forecasters who use multiple indicators). The snowballing technique was the main sampling strategy. Knowledgeable traditional forecasters in FGD's were used to identify key informants with whom semi-structured interviews were conducted. All data was analysed using the thematic analysis method. Data was constructed using a cyclical process to generate themes which consisted of the initialisation (capturing participants' accounts), construction of themes, relating the themes and developing results. From the study, it was found that male and female elderly agro-pastoralists in Bobirwa are more knowledgeable about traditional weather forecasting and use the traditional weather forecasting techniques to inform their decisions, while the less-knowledgeable adults and youth expressed having limited use of traditional weather forecasting in decision making. There were also differences in the use of specific traditional indicators based on the positionality of an individual in the society as well as age and gender. While the participants indicated that traditional weather forecasting is a reliable technique, climate change is believed to have resulted in unpredictable trends in recent years. For example, excessive floods, patchy and reduced rainfall, extensive heat spells with no specific patterns, changes in biological indicators, and thus, present a challenge to these agro-pastoralists. In all, traditional weather forecasting remains a cultural artefact in the community and will always be practised by the agro-pastoralists. However, many elements threaten the existence of the traditional weather forecasting such as the death of custodians of knowledge, the disruptive nature of climate change, youth migration to cities and the ubiquity of modern practices. Further to this, the prevalence of modern practices, for example Christianity, is transforming the use and beliefs of individuals in traditional weather forecasting leading to reduced intergenerational transfers of the traditional weather forecasting. It is prudent to expect that as cultural practices change within societies, cognisant of the fact that culture is dynamic, it is also expected that the use of traditional weather forecasting will change. It should, however, not be construed that the changes in the use of traditional weather and seasonal forecasting are an indication of the unreliability of traditional indicators, but inability of individuals to forecast. In turn, the study recommends the conservation of the traditional weather forecasting and traditionally important biological indicators. This can be promoted through documentation and teaching of traditional weather and seasonal forecasting techniques in conventional educational programmes. Alongside this, integration of traditional and scientific weather forecasting could be used to develop national policies to facilitate effective drought and flood coping strategies that are inclusive and aimed at limiting the traditional weather forecasting knowledge gap among agro-pastoralists of different age and gender groups. Interventions by the government can be redirected to traditional leaders or elders who bear extensive knowledge on traditional weather indicators to create awareness and facilitate knowledge exchange especially in aiding agro-pastoralists to cope with climate variability. Also, for those who are sceptical of traditional weather forecasting, the use of religious gatherings of different denominations can be an option to facilitate awareness raising of coping strategies that can be explored to reduce vulnerability amongst this group of agro-pastoralists by teaching them to adapt to the changing weather using local knowledge.

Keywords: Agro-pastoralism, Bobirwa, decision-making, early warning signs, traditional weather forecasting

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List of Acronyms

AF: Adult Females

AM: Adult males

ENSO: El Niño–Southern Oscillation

EF: Elder females

EM: Elder males

FDG: Focus group discussions

GCM: General circulation model

IPCC: Intergovernmental Panel on climate change

SSI: Semi-structured interviews

TK: Traditional knowledge

VDC: Village development committee

Chapter 1

1.1. Introduction

Climate variability has substantial impacts on humanity (O'Brien and Leichenko, 2000). For instance, rural agro-pastoralists are particularly vulnerable to climate variability as they rely on rain-fed agro-pastoralism for their livelihoods (Batisani and Yarnal, 2010; Nkomwa et al., 2014). In terms of addressing the food security challenge in the world, with a predicted population of 9.6 billion people by 2050 (DeSA, 2013), with the majority of food in Africa being generated through small-scale farmers, climate change poses threats and presents opportunities. Research on climate change indicates that agro-pastoralists will continue to experience prolonged droughts, increase in temperature and shifts in seasons in the foreseeable future (Parry et al., 2007; Madzwamuse, 2011). As such, it is essential to adopt future-oriented studies and approaches to addressing these shifts in seasons and any arising challenge, thus presenting an opportunity to establish the extent that agro-pastoralism is resilient and to develop more resilient agricultural systems. One critical point in coping with climate variability and change, is to have timely and precise weather information to enable knowledgeable decision making to sustain livelihood systems and improve food security (Pulwarty and Sivakumar, 2014). Research indicates that rural agro-pastoralists have historically coped with climate variability by using traditional weather and seasonal forecasting knowledge weather and seasonal forecasts to influence their agro-pastoral practice.

Traditional weather forecasting represents an accumulation of explicit or implicit knowledge, practices and beliefs that have evolved from observation of past climatic events and environmental changes (Masango, 2010). Individuals with traditional weather forecasting knowledge often observe changes in the environment, such as flowering and fruiting of plants, the lunar cycle, and insect behaviour, to generate early warning signs of drought and flood events and provide weather information such as rainfall patterns. It has, however, been recognised that these indicators used in traditional weather forecasting respond to different atmospheric pressures from a scientific perspective. By detecting early warning signs from the immediate environment, traditional weather forecasting enables the development of safeguarding strategies against predicted conditions such as drought and floods (Chang'a et al., 2010; Kolawole, 2014a; Pulwarty and Sivakumar, 2014).
In rural communities, household members, especially the elderly, often demonstrate an understanding of the dynamics and complexity of ecosystems, hence they are often the ones who engage in traditional weather forecasting. The transference of the knowledge, however, may transform from generation to generation (Gemedo-Dalle et al., 2006) and understanding and application may be variated. Different generations are reported to develop newer methods of traditional weather forecasting based on this evolution and changes in weather and species composition that may be observed in their localities (Mogotsi et al., 2011; Nkomwa et al., 2014).

In Botswana, agro-pastoralism is a widely practised economic activity and a livelihood option for many communities faced with limited employment activities (Masike and Urich, 2008; Sallu et al., 2010). Like other areas in semi-arid regions, agro-pastoralists in Botswana are affected by the recurring droughts and flash flooding, which may negatively impact the economic and socio-cultural practices (Mogotsi et al., 2013). Most studies on agro-pastoralism indicate that traditional weather forecasting is practically used for planning farming activities (Orlove et al., 2010). Therefore, the use of traditional weather forecasting is important for reducing the vulnerability of agro-pastoral communities to droughts and floods. The Intergovernmental Panel on Climate Change (IPCC, 2013) report emphasises that decision-making is crucial and should be explored to determine the drivers of mitigating risks associated with climate variability in semi-arid regions. Studies indicate that in Lesotho, traditional weather forecasting has been and is currently being used, to influence making decisions about planting dates, mating livestock, harvesting dates, etc. (Ziervogel, 2001). These indicators include wind, stars, the moon, sun, insects, birds, vegetation. The knowledge that influences agro-pastoralists' decision making in this context is important for sustainable agro-pastoralism practices, conservation of traditional weather forecasting and reducing vulnerability to climate variability (Kolawole, 2015). A study by Kolawole et al., (2014a) indicates that the aggravation of climate variability by climate change may potentially pose questionable doubts to traditional weather forecasting owing to fluctuations in landscape and context on which the knowledge is based. Many discussions tend to indicate that reliability and usage of these traditional weather forecasting techniques may be challenged or weakened in the face of climate change (Mogotsi et al., 2011; Prober et al., 2011; Kolawole et al., 2014a; Ayal et al., 2015).

Additionally, it has been established in literature that the use of traditional weather forecasting is differentiated by social groups namely gender and age (Whyte, 2014; Bhattarai et al., 2015; Sterrett, 2016). As mentioned, it is likely that older people with more traditional beliefs and more observations of different seasons are more likely to have the relevant skills and know-how of using traditional weather forecasting (Mogotsi et al., 2011; Jiri et al., 2016; Rao and Morchain, 2016). From the notion that social groups within agro-pastoral have different levels of understanding traditional weather forecasting, the degree of coping with climate variability may be fragmented, which could be argued to leave some groups vulnerable and less resilient, especially when adopting the traditional methods of rainfed agro-pastoralism. Moreover, with traditional weather forecasting often residing among the elderly, it is under threat from the death of custodians of the knowledge owing to old age (Kolawole, 2014b).

Despite the use of traditional weather forecasting by different social groups, the intensity of long dry spells and flooding experienced in semi-arid regions has led to increased vulnerabilities for subsistent agro-pastoralists. These growing vulnerabilities of agro-pastoralists to climate variability has led to increased enthusiasm by the government to offer support to the subsistent farmers to limit poverty and strengthen different groups and agro-pastoralists in different areas of

Botswana. Specifically, the rise of the Integrated Support Programme for Arable Agriculture Development (ISPAAD) has come into play. The ISPAAD programme has set guidelines and rules that do not follow the traditional methods of agro-pastoralism, therefore could potentially interfere with the individuals' strategies for coping with climate variability. Systems that assume a top-down approach such as the ISPAAD programme have received increased criticism in literature on their exclusion of traditional weather forecasting which may influence the ultimate coping strategies as suggested by Vanclay and Lawrence (1994). A study by Meijer et al., (2015) further emphasises the slow uptake of innovations that are suggested to farmers in Sub-Saharan Africa, which may imply the persistent use of their knowledge, perception, and attitudes to their farming practices.

Using concepts of vulnerability and resilience, different research paradigms, namely risk hazards, social resilience and ecological systems frameworks, emphasise the need to explore understanding of how different individuals cope and the causes and consequences of differential susceptibility (Miller et al., 2010; Perez et al., 2015). Focusing on gender, age, and knowledge of generating early warning signs using traditional knowledge and decision making, we use the social resilience framework to analyse how men and women of different age groups are affected by climate variability and changes in traditional weather forecasting.

1.2. Problem Statement

The purpose of this study is to identify and compare the use of traditional weather forecasting by different age and gender groups regarding planning and decision making in agro-pastoralism within the Bobirwa sub-district.

1.3. Aim and objectives of the research

This thesis aims to provide a comprehensive understanding of how the traditional weather forecast information is generated and used to cope with climate variability by different gender and age groups of agro-pastoralists in Bobirwa sub-district in Botswana. To understand the complexities faced by agro-pastoralists of different age and gender groups during the recurring droughts, the study intends to document indicators used in traditional weather forecasting, i.e. rainfall, winds, drought, floods in the Bobirwa sub-district. Furthermore, the study explores whether different social groups generate the warning signs of drought and floods the same way and determine what constitutes the differences. Finally, within the social groups, the study explores how the traditionally generated warning signs are used to cope with climate variability in the Bobirwa sub-district.

This research forms part of 'Phase 2' (2015-2017) of the Adaptation at Scale in Semi-Arid Regions (ASSAR) research project. The ASSAR research project aims to expand the understanding of climate vulnerability and adaptation in semi-arid regions. It also helps transform the agro-pastoralists' current adaptation measures and promote sustainable development that considers adaptation to "climate-proof" developments and to advance adaptive capacities for vulnerable groups. The outcome of the proposed study will contribute to the research of the ASSAR team, as it is situated within the context of improving knowledge systems on adaptation measures as identified in the Regional diagnostic study (Spear et al., 2015).

This project has three main objectives. These are to:

1. Identify the traditional weather forecasting used by agro-pastoralists in Bobirwa sub-district vis-à-vis farming and general livelihood planning and decision-making.
2. Determine how the use of traditional weather forecasting is differentiated by social groups in the Bobirwa sub-district.
3. Determine changes in the reliability and use of traditional weather forecasting in the face of climate change.

1.4. Organisation of the dissertation

Chapter One: provides the background to the study, motivation and justification, objective and purpose of the study.

Chapter Two: outlines a wide body of literature on how different agro-pastoralists worldwide use traditional weather forecasting as a method of determining early warning system for agricultural. In this chapter, literature on the necessity of traditional knowledge, coping capacities, local beliefs and practices and social structures influence how different social groups conduct traditional weather forecasting in the era of climate change was interrogated.

Chapter Three: provides a detailed description of how data was collected, how it was analysed and ethical considerations.

Chapter Four: gives details of complexities of the traditional weather forecasting and how seasonal agricultural practices are linked to beliefs among individuals of different social groups in the study area. This chapter provides detailed thematic analysis the differences in utilisation of traditional weather forecasting by women and males, and youth, adults and elders for their decision making in sustaining their livelihood options. It also discusses the findings obtained from the research.

Chapter Five: draws important conclusions.

Chapter 2

Literature Review

2.1 Introduction

The purpose of this chapter is to examine the current literature debates and discussions on traditional weather forecasting specifically and its application in agro-pastoralism, to evoke traditional weather forecasting and its usage as coping strategies for drought and floods, and to identify the challenges that agro-pastoralists face in using the traditional weather forecasting. The literature review also provides an opportunity to locate this study in existing research by identifying the gaps which justify the importance of this research. To achieve this, the chapter begins by examining the vulnerabilities of rural agro-pastoralists to climate variability and change in Botswana as well as how traditional indicators play a role in the resilience of agro-pastoralists. In addition to this, the study examines the application of traditional weather forecasts to decision making by farmers in rural communities. However, despite the use of traditional weather forecasting in communities, there are considerable changes to this, and these are also examined to understand the specific changes and why these are occurring. Before delving more deeply into these issues, it is necessary to consider the effects of climate variability and change in Botswana in a broad sense.

2.2. Climate change and climate variability in Botswana

Ecosystems and economies of semi-arid regions are vulnerable to climate variability, weather and climate extremes such as droughts and other existing risks that are aggravated by anthropogenic climate change (IPCC, 2013). The recent climate change scenario assessments estimate some degree of warming to occur in different regions in the near future (Blench, 1999). It has been established that drought, El Niño–Southern Oscillation (ENSO) and reduced rainfall are strongly interconnected with the climate system in Botswana (Dube, 2003). These fluctuations of rainfall and temperature affect ecosystem functioning and human survival. Studies indicate that Botswana receives rainfall that is unreliable and unevenly distributed (Dube, 2003) and is often associated with the increase in temperature (Van Regenmortel, 1995; Kenabatho et al., 2012). In addition, the rainfall variability also brings about droughts and floods (Batisani and Yarnal, 2010; Dedekind et al., 2016). In the past 15 years, Botswana has experienced inconsistent rainfall (Ziervogel, 2016). Although the precipitation is mainly between September and April, the current status shows that rains are starting at different times in varying years (Batisani and Yarnal, 2010; Chagonda et al., 2015). It is within these rainfall seasons that there is an increased chance of long dry spells which may affect seedling development of pastures in Botswana (Veenendaal et al., 1996; Ziervogel, 2016). In Southern Africa, for example, the rainfall season is established to have been reduced by about four weeks (Mapfumo et al., 2016), which reduces the season productivity. With the global warming predictions, Botswana proves to be highly vulnerable to climate change impacts, which could account for less resilience in agro-pastoralism.

More than 80% of the population in Botswana engage in agro-pastoralism for food, employment, investment, and income generation (Van Engelen and Keyser, 2013; FAO, 2014), with up to 90% of the rural labour force directly or indirectly engaged with agro-pastoralism. Despite the established increase in rainfall variability, the majority of the agro-pastoralism in Botswana is rain-fed (Batisani and Yarnal, 2010; Nkomwa et al., 2014). With an estimate of 80% of the Botswana agro-pastoralists reliant on the dry land arable agriculture (Botswana Government, 2006), the impacts of drought, ENSO, and rainfall variability can be catastrophic and challenging to food security in the country (Dube, 2003; Zhou et al., 2005; Archer et al., 2007; Mogotsi et al., 2013). According to Fraser et al., (2011), when using dynamic ecological and environmental change models, climate-induced drought may cause a decline in agricultural productivity. When using a general circulation model (GCM), the Southern African core climate change scenario on staple foods, a 36% decline in maize and 31% in sorghum yields is projected (Chipanshi et al., 2003). Mogotsi et al., (2013) confirm that rural households in the Bobirwa sub-district face increased livestock and crop failures during droughts. The rural communities, however, used biodiversity as a buffer against impacts of variation in climate and catastrophic events through diversification of crop and livestock production, wild fruit harvesting or other forms of survival. Considering all this, coping strategies, therefore, become an integral component of the future of the communities. A growing body of literature suggests that rural communities often use traditional weather forecasting as coping and adaptation strategies to mitigate impacts of climate variability and climate change (Kolawole et al., 2014a; Chengula and Nyambo, 2016; Kolawole et al., 2016). Drawing from the theory of social resilience, we assess the use of traditional weather forecasting by different age and experience.

2.3. Theoretical framework

This study is grounded in and informed by the social resilience conceptual framework. Social resilience alludes to "the capacity of social groups and communities to prepare for and/or respond positively to crises" (Maguire and Hagan 2007:16). Social resilience consists of three dimensions, namely: "(a) coping capacities, expressed as the ability of social actors to cope with and overcome all kinds of adversities (b) adaptive capacities, expressed as the ability to learn from past experiences and adjust themselves to future challenges in their everyday lives (c) transformative capacities, which is their ability to craft sets of institutions that foster individual welfare and sustainable societal robustness" (Keck and Sakdapolrak, 2013; Norris et al .,2008). The social resilience concept further posits that social groups are differentiated, hence the level of resilience and capacity of response to threats will be different within a community (Maguire and Hagan, 2007; Eakin et al., 2014). This suggests that different social groups are impacted upon by crises differently. Social actors' knowledge, perceptions and attitudes therefore influence their coping and adaptive capacities.

Maguire and Hagan (2007) and Brown (2014)'s conceptualisation of social resilience will be used to explore issues in this study. Their conceptualisation aptly links with analysis incorporating responses by agro-pastoralists of different age groups, who have accumulated different knowledge and have different attitudes towards different knowledge bases.

2.4. Traditional weather forecasting as a tool to enhance resilience

For agro-pastoralists to be resilient against the challenge of climate change and variability, as well as improve productivity, there is need for mechanisms to anticipate when climate extremes are likely to occur. Attempting to conduct traditional weather forecasts is a major challenge and currently, not widely adopted and disseminated for use by the different governmental institutions; rather, scientific techniques are much more common. However, rural communities such as Bobirwa sub-district, like many other communities, rely on traditional approaches to make seasonal forecasts. In using traditional weather forecasting, there are many different indicators which agro-pastoralists use to make forecasts and these indicators are not predefined but rather, emerge through how agro-pastoralists interact with their lived environment over time (Drahos and Frankel, 2012; Kolawole et al., 2016). However, there is limited information of the historical documentation of indicators, beliefs including mythical figures, environmental conditions encompassing changes (Murphy et al., 2016). The knowledge is rather embedded in the many traditional communities and how they use the knowledge to inform their cultural activities. The intergenerational dispersal of this knowledge is largely shared by the elders to the younger generation through stories and visually taking note of the indicators seasonally. Ecological sites and possibly indicators key in predicting the traditional forecasting are prone to threats of extinction as the elders pass on.

2.4.1. Traditional weather forecasting indicators used to generate seasonal weather information

Globally, traditional weather and season forecasters have been noted to use similar approaches to predict the weather. These forecasters firstly indicate that they use lunar cycles, which includes observations of the shape and position of the moon and the movement of stars to identify the likely changes in seasons and also predict rainfall patterns (Clarke, 2009; Jiri et al., 2016). Secondly, the traditional weather forecasters use phenological knowledge to generate their weather information. According to Armatas et al. (2016), phenology is "the study of recurring plants, fungi and animal life cycle stages especially as they relate to climate and weather". The phenological processes such as developmental stages of plants, animals and fungi triggered by atmospheric moisture and temperature often serve as indicators of rain and drought (Chisadza et al., 2015; Kolawole et al., 2016). Finally, the use of atmospheric conditions such as the wind strength and direction of flow, types, direction of flow and colour of clouds, temperature are considered key indicators of weather information used by traditional forecasters. Norms such as traditional weather and season forecasting are used to guide seasonal timing for agricultural activities (Armatas et al., 2016).

2.4.1.1. Plant phenology as an indicator for weather forecasting

Most plants produce new leaves, and flowers, which most communities show to be seasonal variations. Peaks during dry seasons are characterised by many plant species concentrating on leafing and flowering around the start of the rainy season (van Schaik et al., 1993). However, in different locations, certain plants flowering abundantly, and budding is used to indicate the onset of rainfall, good rains or drought, depending on the species. Traditional weather forecasters have observed these changes and associated them with weather patterns in their localities. Plants that indicate good rains include *Acacia* spp and *Ficus carica* (Zuma-Netshiukhwi et al., 2013; Chisadza et al., 2015) and these species have been used to signal drought and particular rainfall patterns. Other examples of plant phenology used by different countries are illustrated in Table 1. A body of literature indicates that, for successful flowering in some plant species, a succession of cold nights and warm days are required. Also, violent heat and/or winds may cause senescence of flowers (Kazan and Lyons, 2016), which, when observed, farmers associate with impending rainfall. This is appropriate as violent heat and winds increase pressure in the atmosphere which could lead to rainfall incidents (Stott et al., 2016). Furthermore, plants have been observed to have the ability to sense future climatic conditions (Ohama et al., 2017). For example, before drought occurs, the plant increases its survival potential by reducing its food requirement and shedding flowers and leaves before pollination (Speranza et al., 2010).

Table 1: Traditional indicators for weather based on plant phenology

Indicator	Description	Significance	Country	Reference
Adansonia digitate	Leaf sprouting and fruiting	Determine the onset of the rain	Tanzania	Elia et al., 2014
Acacia spp.	Substantial fruiting	Onset of rains	Botswana	Mogotsi et al., 2011
			Kenya	Kagunyu et al., 2016
Ximenia Americana	Flowering	Indicate the onset of rains	Tanzania	Chengula and Nyambo, 2016
Brachystegia speciformis	Heavy flowering of flowering of trees.	Indicating a good quality imminent season with abundant rainfall.	Tanzania	Chang'a et al., 2010
Dalbergia boehmii	Partial shedding of leaves	A good year	Tanzania	Elia et al., 2014
Uapaca kirkiana	Heavy flowering	Signifies drought in the imminent season	Tanzania	Chengula and Nyambo, 2016

Plant phenology such as flowering, leaf development and fruiting are dependent on atmospheric pressure. However, as a result of climate change which may cause rapid and frequent changes in climatic conditions, the plant phenology processes are becoming increasingly inconsistent (Walther et al., 2002; Cleland et al., 2007; Matthews and Mazer, 2016). The inconsistencies in climatic conditions and subsequently plant phenology may affect individuals who depend on and use plant phenology in from July to September as an indicator for seasonal rainfall. For instance, due to increased average temperatures, flowering could be induced (Parmesan, 2006; Nakamura et al., 2016), which might not reflect the onset of rainfall. Therefore, it is critical to understand how the changes in climatic conditions are affecting specific plants used for traditional weather forecasting in communities. But this remains a challenge for most rural communities who, at the time of the study, showed a lack of understanding of the complexities relating to physiological changes in plants that are related to impacts of climate change.

2.4.1.2. Animals, birds and insects as indicators for weather forecasting

The behaviour of animals and certain insects plays a key role in the traditional weather forecasting. Indicators such as animals mating, an influx of birds such as sparrows, the migration of birds, frogs making a noise, the appearance of grasshoppers and swarms of ants, have been and are used to signal either the onset of rains, or the quality of the season in terms of rainfall (Zuma-Netshiukhwi et al., 2013; Kayombo et al., 2014; Chisadza et al., 2015). Additional signs that are used are illustrated in Table 2. Firstly, insect behaviour is used by traditional forecasters in Tanzania (Chang'a et al., 2010) and Botswana (Kolawole et al., 2014a). Typically, for most insects to survive, they have developed proficiency at monitoring atmospheric pressure related to rainfall using their antennae (Guerenstein and Hildebrand, 2008; Davidson et al., 2016). Their antennae are constantly active as they host organs of taste, smell and touch (McFarlane et al., 2015). At high humidity in the atmosphere, different insects respond accordingly. Therefore, the action that the insects use to avoid risk from rainfall has been observed by the different communities and this is used as indicators of rainfall.

Secondly, migratory birds are used by traditional forecasters in, for example, Tanzania, Uganda, Botswana, South Africa, Australia (Table 2). Birds' breeding and timing of migration are physiological reaction to changes in seasonality are important indicator of weather in any given site. For example, when sites become favourable with optimum temperatures, high humidity and adequate winds, the birds tend to flock towards these areas for breeding. However, the association of appearance of bird species being an indicator of rainfall is a measure of birds in pursuit of optimum breeding temperatures. Current debates are focused on the credibility of the use of birds as indicators for weather in the Anthropocene phase. Studies indicate that climate change has the potential to be an influence on the future breeding, migration and wintering of birds world-wide. In the same way that research elucidates that currently bird populations have already begun to respond to the current warming climate by changing arrival time and/ or departure time in Southern Africa (Bussière et al., 2015). With further warming that is predicted, the bird indicators may be unavailable to the community, especially that the birds are migratory. This implies that climate change may have a negative impact on the communities who use this as a method of generating their weather forecasts.

Table 2: Traditional indicators for weather forecasting based on bird behaviour

Indicator	Description	Significance	Country	Reference
Hirundo smithii	Appearance of these birds	Indicates above normal rains	Tanzania	Elia et al., 2014
Centropus superciliosus	Appearance and a particular chirping	Onset of the rains	Tanzania	Elia et al., 2014; Chengula and Nyambo, 2016
Bubulcus ibis	Appearance	Bad season	Tanzania	
			Uganda	Okonya and Kroschel, 2013
Spodoptera exempta	Appearance	Signifies abundant rainfall in the upcoming season.	Tanzania	Chang'a et al., 2010
Spodoptera exempta	Appearance	Signifies abundant rainfall in the upcoming season.	South Africa	Zuma-Netshiukhwi et al., 2013

2.4.1.3. Astronomical cues as indicators for weather and seasons

Astronomical cues that are used by traditional weather forecaster include, but are not limited to, using the moon, sun and the stars. For example, the lunar cycle, which is phases of the moon as observed from Earth, plays a key role in predicting for rainfall. According to Kohyama and Wallace (2016), the lunar gravitational and semidiurnal tides are directly influenced by relative humidity; hence when the moon is observed from different angles, it may signify the amount of moisture in the atmosphere. Therefore, relative humidity in the atmosphere is used to generate weather information. In South Africa, it is widely believed that when a moon crescent is facing upwards, it indicates less rainfall, whereas when facing downwards, it indicates the onset of rainfall (Zuma-Netshiukwi et al., 2013). Another common example used in traditional weather forecasting is the movement of particular stars. In Botswana, Malawi and Zimbabwe, stars moving from the west to east signify the onset of rainfall (Mogotsi et al., 2011; Kalanda-Joshua et al., 2011; Shoko and Shoko, 2013).

2.4.1.4. Atmospheric conditions as indicators for weather and seasons

Other traditional weather forecasting tools include atmospheric conditions such as mist, swirling winds, fog, cloud shapes and colour, wind directions and intensity, which, when observed, can be used as early warning signs of drought or floods by agro-pastoralists. Table 3 shows that some indicators based on atmospheric conditions are used to gauge the upcoming rainfall pattern, drought and onset of rainfall. With all the traditional weather forecasting, the interpretation of the indicators is location-specific and may prompt different interpretations of each scenario within each locality (see Table 3; Orlove et al., 2010; Zuma-Netshiukhwi et al., 2013; Kayombo et al., 2014).

Table 3: Traditional indicators for weather using atmospheric conditions in different countries

Indicator	Significance	Country	Reference
Nimbus clouds	Appearance in the morning and evening indicate the onset of rains	Uganda	Okonya and Kroschel., 2013
		Kenya	Speranza et al., 2010
		Botswana	Mogotsi et al., 2011
Winds from the west or the north	Onset	Botswana	Mogotsi et al., 2011
Fog	Dense fog in the morning shows there will be clear skies and no rain	Botswana	Mogotsi et al., 2011
Cold winters	Possibility of hailstorms in the imminent season.	Tanzania	Chang'a et al., 2010
High temperatures	The rain onset is near	Tanzania	Chang'a et al., 2010
		Botswana	Mogotsi et al., 2011

2.4.2. Applying traditional weather forecasting in decision making

Traditional weather forecasting is important to households in rural communities whose livelihoods depend largely on agricultural activities (Mogotsi et al., 2011). Moreover, with climate variability being a common phenomenon in semi-arid regions, the ability to predetermine weather events can reduce the impacts of intensive droughts and floods to curb challenges of poverty and food insecurity (Codjoe et al., 2014; Jiri et al., 2015). Indeed, residing in semi-arid regions necessitates improved decision-making for agricultural activities to mitigate potential losses given the current threats of climate change. Decision-making is a complex process that dictates the success or failure of mitigating risks. It is influenced by an individual's knowledge, background and experience. Okonya and Kroschel (2013) argue that despite the individuals' knowledge and experience in traditional weather forecasting, their decision-making process can be clouded by increasing uncertainty of weather changing conditions and changes in beliefs.

Research shows that application of traditional weather forecasting is linked to constant planning; involving strategic and operational decisions such as what to produce, fodder farming, water harvesting, timing of harvest, harvesting alternative foods, and storing food post-harvest breeding livestock and how much, and reducing the area of cultivation, improving soil quality (Mapfumo et al., 2016). Literature indicates that traditional weather forecasting techniques pre-determine potential future weather conditions such as rain, including floods and drought, winds/storms, heat (Galacgac and Balisacan, 2009). It has been established that decision-making is linked to coping strategies which are embedded within traditional value systems and religious beliefs (Murphy et al., 2016). For this reason, it comes as no surprise that the spiritual dimensions of weather are said to be controlled by ancestors or God (Orlove et al., 2010) and in some instances, weather-related problems are often perceived as punishment from the governing spirits of ancestors or God (Speranza et al., 2010). In that case, worshipping rituals and offerings are done to appease the Gods at Rainmaking ceremonies (Berkes et al., 2000; Nelson and Stathers, 2009; Kolawole et al., 2014a), which constitute traditional weather forecasting.

Above all, traditional weather forecasting is also being used by households to manage resources efficiently, improve agricultural productivity and change behaviour, for example food budgeting and deciding on alternative income sources (Mapfumo et al., 2016). However, even though traditional weather forecasting plays a key role in decision-making, there are also several other factors which inform these decisions and traditional weather forecasting cannot work in isolation. Also, the adoption and use of traditional forecasting differs among the social groups.

2.4.3. Use of traditional weather forecasting among different social groups

With weather forecasting identified to have a critical role in the decision making of agro-pastoralists, (Roudier et al., 2014), it is important to consider the use of traditional weather forecasting by different social groups. This is because societies, in general, are made up of different strata of groups. The recent IPPC report has recognised the distinction and vulnerability to climate change of different groups of people categorised by age, sex, ethnicity, religion and many other social factors, is referred to as social differentiation (Masundiri et al., 2016). This means there are no generalised risks or opportunities to cope with risks of climate variability in agro-pastoralism. Also, the arrangement of roles, responsibilities and relations between men and women of different social groups, ages, educational and marital statuses is critical in the coping strategies and resilience of different social groups. The social differentiation has a major impact on the individuals' decision-making and approach in agricultural activities and general livelihood in life, for example climate adaptation. The focus of this research is traditional weather forecasting in rural areas. Considering that the rural communities can be socially disaggregated (by social factors), it is critical therefore to understand how social differentiation may have an impact on the traditional forecasting.

The first and most common social differentiation factor is gender. In many development-oriented studies, gender has been examined particularly to address the 'oppression', 'limited participation in decision- making' and 'oversight' of women. Historically, the African culture has 'allocated' specific duties to men and women and these have become acceptable standards. Whyte (2014) further highlights that the responsibilities assumed by women in communities expose them to harm from climate change and changes in the environment. For instance, the majority of decision-making duties are entrusted to men, while women take other duties (Whyte, 2014; Bhattatrai et al., 2015; Jost et al., 2016; Mapfumo et al., 2016; Mnimbo et al., 2016). However, the current challenges of climate variability and change are complex and thus, require equal participation of men and women if solutions are to be developed. Despite this, there are still societies in which 'structural inequalities' persist and thus, do not provide equal chances of participation to men and women, but this cannot be generalised. For this reason, it is critical to examine the processes, progress and challenges of 'empowering' women in rural communities to provide them with an opportunity to participate in problem-solving, for example through forecasting.

Further to the above, age is another social differentiation factor. Previous studies indicate that rural communities' demographics have been transforming over time. It is prudent to indicate that rural communities are characterised by elderly people, with young people migrating in search of better opportunities. However, there are also communities with a considerable balance between the old and the young. Young and elderly people have different approaches to decision-making and solving problems, including climate-related problems. In forecasting, the young people are often taught traditional forecasting cues and approaches by the elderly and their acceptance of these methods are often affected by science and technology. The majority of young people are inexperienced in relation to the use of traditional indicators, but are better acquainted to modern approaches, for example relying on technology to inform their decision. As a result of this, the age of an individual can be a critical factor in determining the attitude, perception and dependence on traditional indicators as well as traditional forecasting of individuals.

Droughts and erratic rains are increasingly being experienced within semi-arid regions, including Botswana, and are said to be likely to have adverse effects on human livelihoods and productivity within communities in the near future (Zhou et al., 2005; Mubaya et al., 2012; Mogotsi et al., 2013). In hopes of providing for the families, individuals often are often prompted to cope with the adversity and changes of the imminent threats. When determining the capacities of the individuals to cope, it is crucial to assess the decision-making processes of these individuals during increased incidents of climate variations in this case. Decision-making is often disproportionately articulated to different cultural responsibilities and experiences of individuals, especially in terms of gender, age and livelihood options (Murphy et al., 2016). One of the contributing factors to social differentiation in agro-pastoralism has been linked to gender, therefore indicating that that the vulnerabilities of females and males are likely to vary considerably. When assessing the use of traditional weather forecasting, most studies focus on profiling different indicators used in traditional weather forecasting, with little emphasis on the knowledge of the other gender group, including the non-forecasters. The urgent nature of research on profiling different indicators consequently channels all the energy to addressing issues relating to indicators and their use in agro-pastoralism rather than determining the knowledge of different age and gender groups. This creates the danger of overlooking gender dynamics involved in different roles that exist in social structures. Studies in Botswana, in the Kgalagadi region, Bobonong and the Okavango area, for example, have determined that agro-pastoralists use traditional weather forecasting to cope with climate variation (Mogotsi et al., 2011; Kolawole et al., 2014b). On the other hand, these studies do not indicate the use of the indicators among different gender and age groups. Should the knowledge be constrained to one cluster of the community, this could pose a threat to the continuity of the knowledge and may depict vulnerability and resilience to be varied.

2.4.4. Challenges in traditional weather forecasting in retaining sustainability among agro-pastoralists

Traditional weather forecasting remains a popular practice in many rural communities. However, despite the use of this practice, there are also many challenges associated with the use of the practice. Firstly, traditional weather forecasting is "… invariably locally and geographically specific" (Briggs, 2013). Each community uses different cues as communities interact differently with their lived environments. As such, there are no universally agreed indicators which can be used in the weather forecasting. The challenge with this is that in different communities, certain 'indicators', for example birds/trees, may carry different meanings.

The increased modernisation of societies and reliance on technologies is also another major change within communities affecting the use of and dependence on traditional weather forecasting. The process of globalisation has resulted in the modernisation of many systems forecasting not being spared (Jiri et al., 2016). Development interventions relating to climate variability and change (which also relate to weather forecasts) in developing countries are normally externally funded and, thus, advocate the use of pre-defined approaches which mostly use technologies. Thus, this leads to traditional weather forecasting being perceived rather as an impediment to the achievement of intervention objectives (cf. Jiri et al., 2016). Further to this, another key challenge is the lack of systematic documentation of traditional weather forecasting (Chang'a et al., 2010). There are many communities with various traditional forecasting techniques and yet, these techniques are undocumented, making it extremely difficult to access or determine vulnerabilities of individuals. Scholarly work on traditional weather forecasting is also considerably limited and often context-specific, making it extremely complex to generalise (Armatas et al., 2016). Traditional weather forecasting techniques and knowledge are 'held' by the elderly within communities, especially those above 40 years (Kalanda-Joshua et al., 2011). However, as these custodians of traditional forecasting techniques/knowledge age, there is often a challenge that communities fail to 'document' this knowledge, resulting in considerable loss of the knowledge. There is need, therefore, for documentation of traditional forecasting for this knowledge to be shared and disseminated to other generations. However, the current documented traditional weather forecasting remains incoherent in terms of differentiating vulnerabilities and coping capacities of different age and gender groups.

Further to the above, traditional weather forecasting is often open to misinterpretation. Cetinkaya (2009) argues that there are extremely limited education and awareness programmes relating to traditional weather forecasting in rural communities which can transmit the knowledge. Even the school curriculum in most rural communities revolves around scientific techniques marginalising traditional weather forecasting. In most rural societies, young people are also increasingly spending less time with the elderly, and therefore, do not have a chance to learn and understand the dynamics of traditional weather forecasting. Therefore, applying knowledge that is not fully understood could lead to increased vulnerability to climate variability and mismanagement of natural resources such as soil. Traditional weather forecasting is passed from one generation to another through oral stories, cultural and social activities. However, as societies become more modernised, social activities are changing even in rural communities. Young people are increasingly migrating to cities in search of employment and as such, the passing of traditional weather forecasting techniques from one generation to another is increasingly becoming complicated. Also, youth are taking new opportunities, for example they are less involved in conventional practices in rural communities and undertake employment reducing the necessity for them to accumulate or use the traditional weather forecasting.

Besides challenges outlined, traditional forecasting's reliability is another challenge (Mogotsi et al., 2011). From a study conducted in Bobonong, it was found that less than 20% of the respondents had indicated that traditional indicators are reliable. Additionally, Mahoo et al., (2015) further illustrate the low respondents in Tanzania who find the traditional weather forecasting unreliable. The mere observation of specific indicators does not always result in anticipated outcomes and thus, accuracy and reliability remain some of the key challenges in the use of traditional weather forecast. The challenges of accuracy and reliability do not only affect traditional weather forecasting but also, it affects even scientific forecasts.

2.4.5. Changes in the application of traditional forecasting

There are contestations on the use of traditional weather forecasting in informing decision-making in rural communities (Reid et al., 2002). However, it is certain that over time, there have been changes in the use and reliability of traditional weather forecasting. Changes in the use of traditional weather forecasts have been necessitated by many factors, including but not limited to, cultural shifts, demographic changes and social changes. The changes in the use of traditional weather forecasting have also been expedited by globalisation and the expansion of technology (cf. Gómez-Baggethun et al., 2010). The application of traditional forecasting is changing drastically due to the extreme variability and changes in climatic conditions – climate change (Okonya and Kroschel, 2013; Kolawole et al., 2014a). Mapfumo et al. (2016) also suggest extreme variations in seasons and as such, these changes are increasingly affecting the application of traditional weather forecasts. Rural communities often use historical experiences and accumulated knowledge to make weather forecasts using environmental indicators. However, the complexity of climate change and its contribution to the inconsistency of seasonal outcomes is a major change affecting the use of traditional weather forecast.

Also, one major change which has occurred in the last few years has been the integration of traditional weather forecast with climate science – leading to coproduction of knowledge (Armatas et al., 2016). Orlove (2010) indicates that farmers in rural communities have become increasingly willing to integrate traditional weather forecasting with climate science to predict the potential future. The increasing variability of rainfall and recurrent droughts which traditional weather forecasting techniques are failing to predict with accuracy, has prompted farmers in rural communities to also consider climate science and thus, agro-pastoralists take scientific seasonal forecasts into account when making farming decisions. However, even though there is a considerable increase in the integration of traditional and scientific knowledge, Kolawole et al., (2014b) found that over 76% of agro-pastoralists still relied on traditional weather forecast, mainly due to poor adoption of scientific information. In all, scientific forecasts are poorly accessible to many rural communities and as such, even though there is potential integration, this is occurring at an extremely slow pace.

The demographics in rural communities are also increasingly changing, affecting the use of traditional weather forecasting. In previous decades, much of the population in rural communities was less educated, had extensive experience in agro-pastoralism (for example lived the entire life on agriculture) and was much older. However, the population demographics in rural communities are changing. For instance, farmers in these areas are becoming relatively educated (through extension education), and have diluted understanding and appreciation of culture. Kolawole et al (2014b) indicate that there is a correlation between a farmer's characteristics and perception as well as use of traditional weather forecasting. Therefore, the changing patterns (decline) in the use of traditional seasonal forecast reduces the macro climate monitoring which is important in both conservation and accuracy of factors specific to the locality. Furthermore, in response to climate change and other related agricultural challenges, farmers are transforming their agricultural practices, for example intensification of farming activities. Gómez-Baggethun et al., (2010) further indicate that farmers are embarking on new farming practices considering diverse challenges. Naess (2013) shows that changes in internal and external processes affect the use of traditional weather forecasting. Therefore, transformation of activities within the agricultural activities, for example intensification of agro-pastoralism, affects the decision of farmers to use traditional weather forecasting.

Traditional weather forecast is linked significantly to cultural activities and social issues. However, in many African communities, there is an increase and transformation of religious beliefs for example increasing churches and increasing numbers of Christians (Ayal et al., 2015). The cultural practices of traditional seasonal forecasts are condemned by religious practices and as communities become more involved in religious activities, the use of traditional weather forecast also changes (Orlove et al., 2010).

Summary

The review of literature in this chapter has concentrated largely on empirical data of traditional weather forecasting and its application in agro-pastoralism. At household level, effects of climate variability and coping with droughts and floods may be limited by knowledge and social responsibilities of individual agro-pastoralists. Certain aspects of the traditional weather forecasting may, however, be threatened by impacts of climate change, changes in the social structure and possible extinction of specific indicators used for forecasting. Despite this, individuals' ability to assess risks of climate variability is crucial and constitutes to a greater extent in building resilient agricultural communities. Thus, this chapter provides a basis for assessing the use of traditional weather forecasting and its possibilities to explore the interplay of different age and gender groups and improve resilience of agro-pastoralists.

Chapter 3
Research Methods
3.1. Introduction

The purpose of this chapter is to indicate the study area and the methods that were used to collect and analyse data used for the thesis. The thesis takes a form of qualitative research, utilising a case study to examine in-depth traditional weather forecasting techniques and their application in agro-pastoralism and decision-making by different age and gender groups rather than generalising.

3.2. Research Methodology

The case study was designed to analyse the use of traditional weather forecasting in planning and decision-making on agro-pastoral activities; changes in traditional weather forecasting in terms of its reliability; and how the traditional weather forecasting is differentiated by age and gender. Guided by the objectives described in Chapter 1, the case study made use of different ethnographic methods for data collection to develop a comprehensive understanding of phenomena. These included key informant interviews (KII), focus group discussions (FDG) and semi-structured interviews (SSI) (see Appendix). Thus, the study utilises methods triangulation, which is viewed as a qualitative research strategy to test validity through the convergence of information from different sources (Golafshani, 2003). All participants involved in the study signed a consent form and all interviews were audio recorded. A total of six focus groups were undertaken with agro-pastoralists who were differentiated by age and gender. The participating adult and elderly agro-pastoralists were registered with the department of agriculture, whereas the youth participants were registered with the Botswana youth development fund in the Bobirwa sub-district. The research was executed in two phases namely documentation and validation. Information was collected specific to each group by responding to the three questions, namely: (1) what indicators are used in traditional weather forecasting, (2) how the generated weather information advises decision-making in agro-pastoralism activities, (3) changes that have been observed regarding indicators and the use of traditional weather forecasting among agro-pastoralists.

In the documentation phase, agro-pastoralists who were characterised as traditional weather forecasters and non-forecasters (Table 4) were interviewed with the aid of a semi-structured guide consisting of questions that determined usage of traditional weather forecasting. Semi-structured interviews and focus group discussions were used to make an enquiry on traditional weather forecasting including planning and decision-making to cope with climate variability. The participants who are traditional weather forecasters were asked about the indicators they use to determine the onset and the quality of the upcoming rains. The quality of rainfall encompasses incidents of good rainfall, droughts and floods. Participating agro-pastoralists were asked to describe the behaviour of, for example plants, insects, astronomical cues, to establish similarities in usage among different social groups.

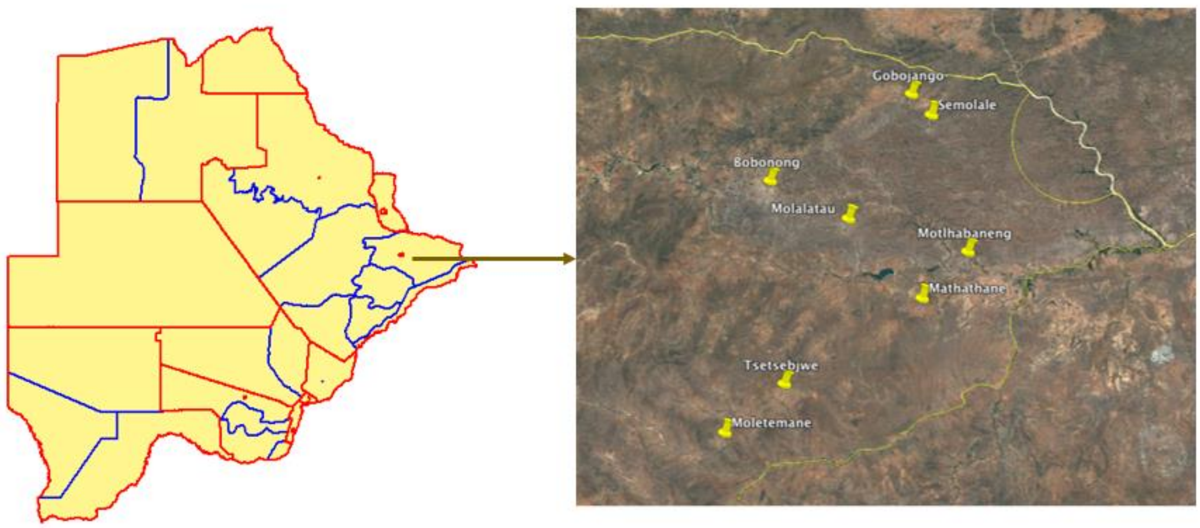
At sub-district level, the community structure includes chieftaincy and village development committees, therefore conducting any form of research in the community needs clearance by different structures in the village. To acquire community clearance, to commence with data collecting, a series of approvals were acquired from the chiefs and sub-chiefs, district councillor, village development committee, and the Department of Agriculture from Bobirwa sub-district due to their roles in communities and out of cultural respect. it is well known that the, chiefs' positions are key in the traditional framework for traditional forecasting and they are actively involved in addressing matters around rain-making ceremonies, coordinating and facilitating weather predictions and the cropping season. The main aim of this focus group was to determine the system that traditional weather forecasting follow and to determine different indicators used in forecasting. The subsequent interview was with the village development committee (VDC). The village development committees' duties are to prioritise village needs and speak on behalf of the communities to local authority in terms of development related matters. Also, the VDC members play a major role in social welfare of communities. A focus group discussion of the top-ranked VDC members for the district was conducted to scale the individuals' personal engagement with the traditional weather forecasting. It was also a gesture of following the protocol of informing the VDC of researchers' interaction with their communities. Once the local authorities had been questioned, permission was granted to proceed with the data collection. Focus group discussions and semi-structured interviews were conducted with the community members, both forecasters and non-forecasters. To ensure consistency of data collected, non-forecasters were requested to give a sense of how much they plan and make decisions for their agro-pastoral activities. Other sets of data information gathered included the agro-pastoralists' demographic profiles.

3.3. Study site

3.3.1. Overview of the study area

The study was conducted in the Bobirwa sub-district of Botswana (Figure 1). The Bobirwa sub-district is located in the eastern region of Botswana near the border with Zimbabwe and Northern South Africa along the Limpopo basin and has an average population of 19 000 (Knoema, 2016). To represent the findings from the Bobirwa sub-district fairly, participants were drawn from eight villages outlined in Table 1. These 8 of 12 villages in Bobirwa sub-district were selected based on their accessibility including obtaining permission to conduct the study in the area. Accessibility was determined by the village extension officers' attendance the introductory meeting and their availability during the course of the data collection. The livelihood system that is predominant in the Bobirwa sub-district is characterised by communities with agro-pastoralism as the main source of livelihoods. Majority of these agro-pastoralists are dependent on rainfall as rain-fed crop farming, subsistence and commercial cattle, goats and sheep rearing, wild fruit harvesting, and working on community development projects such as *namolaleuba*. The agro-pastoralists here rely on traditional weather forecasting to make decisions on cropping and manage their livestock (Mogotsi et al., 2011). The Bobirwa sub-district is dominated by semi-arid weather and is vulnerable to erratic and unreliable rainfall and high temperatures. The mean annual rainfall is 350 mm from erratic showers within the rainy season (Alemaw, 2012) and there is an average temperature of 33 °C in the rainy season, which occurs mostly in the period of October to April (Department of Meteorological Services Data, 2016). The vegetation consists of mopane woodlands and Acacia tree/shrub savanna.

Figure 1 Bobirwa sub-district, Botswana. These data were extracted from the GADM database (www.gadm.org), version 2.8, November 2015



3.4. Sampling

In preparation for fieldwork, clearance to engage the agro-pastoralists was granted by the local and traditional authorities – the local authority being the district commissioner and the traditional authority being the chief of the sub-district based in Bobonong. The Department of Agriculture technicians were also contacted to assist with recruiting participants based on gender and age criteria on my behalf. The farmers were involved based on their interests, availability and willingness to discuss the topic. The interaction with the agro-pastoralists was to: i) identify the traditional weather forecasting is used by agro-pastoralists in Bobirwa sub-district vis-à-vis farming and general livelihoods planning and decision-making, ii) determine how the use of traditional weather forecasting is differentiated by social groups in the Bobirwa sub-district; and iii) explore changes in reliability and use of traditional weather forecasting in the face of increased incidents of drought and flash floods.

The recruitment of informants was deliberate, based on the livelihood option of farming and was stratified to ensure heterogeneity with regard to gender, age and livelihood (Rao and Morchain, 2016). In this study, participant selection criteria included using purposive sampling to select a total of 101 agro-pastoralists who use or do not use traditional weather forecasting techniques to influence their decisions. From the 101 participants, the sampling strategies in this study comprised a total of 54 agro-pastoralists (37 forecasters and 17 non-forecasters) engaging in semi-structured interviews; 47 individuals took part in focus group discussions and 11 in key informant interviews, purposively selected for each category. The reason for using purposive sampling was that the study aimed at identifying specific skills, knowledge, or practices that influence coping strategies by agro-pastoralists; therefore, sampling was related to the research questions of the study. In many surveys, this sampling method is used for collecting information on ecological knowledge that is guarded by elders and ideal for determining cultural significance of particular knowledge (Tongco, 2007). The agro-pastoralists baseline study was conducted and aimed at mapping out gender differentiated information about traditional knowledge, concerns opportunities and visions relating to traditional weather forecasting. To the extent feasible, the participant groups included agro-pastoralists of different age groups namely youth (21-35); adults (36-64) and elders (65+). The age groups reflect the national age group division. Furthermore, the researcher also used a snowball sampling strategy, according to Oliver (2006), to recruit participants who were well known within the communities to practise traditional weather forecasting and those who disbelieve traditional weather forecasting for providing relevant data.

3.4.1. Description of explanatory variables

In this study, the explanatory variables are selected on the basis of the survey with the agro-pastoralists. The relevant explanatory variables are outlined and described in Table 4.

Table 4: Description of explanatory variables

Explanatory variable	Description
Age	Age influences agro-pastoralists' experience with different seasonal changes and different environmental cues used in traditional weather forecasting. Thus, it is expected that elders (65+) will have more knowledge than the youth (21-35) (Kolawole et al., 2014a).
Gender	Climate variability does not affect males and females in the same way, as much as their abilities to adopt measures to avoid or overcome impacts are differentiated.
Knowledge of traditional weather forecasting	Agro-pastoralists who indicate to use traditional weather forecasting (phenology, astronomical and atmospheric cues) as early warning signs to climate variability. Due to different knowledge accumulation on the different cues, the study accommodates those who generate the information or those who access the weather forecasts information from others.
Experience in traditional weather	Agro-pastoralists with adequate knowledge in traditional weather forecasting, such as the ability to identify traditional indicators of weather, could be varied by age and gender. Thus, the participants were categorised according to the level of knowledge they had, expressed in three levels, namely forecasters and believers, non-forecasters and believers, and non-forecasters and non-believers. The

	forecasters and believers are the individuals who actively practise the weather forecasting, non-forecasters and believers are the individuals who somewhat know some indicators but are not confident with the prediction, whereas the non-forecasters and non-believers fully condemn the use of traditional weather forecasting.

3.5. Methods

3.5.1. Semi-structured interviews with agro-pastoralists

To collect data for this study, semi-structured interviews were selected as it is the most common method used in traditional knowledge research. A semi-structured interview guide was developed to predetermine open-ended questions and pretested using five agro-pastoralists in the study area. Based on the feedback obtained during the pre-testing, adjustments were made on the flow and clarity of questions to ensure consistent phrasing of questions. Using the semi-structured interview guide, agro-pastoralists, both males and females of different age groups, were interviewed. During administration of the semi-structured interviews, all questions were translated into the local language. The questions included in the semi-structured interviews consisted of agro-pastoralists' demographics, traditional indicators and determinant factors for farm decision. As indicated in Table 4, the ability of different social groups to forecast and use traditional weather forecast differs. For instance, other social groups can make seasonal forecasting using traditional knowledge and those who are unable to do so, depend on intermediaries to share the forecasts made by those who can. Using the semi-structured interview guide, the questions were asked relevant to the knowledge of participants on the use of traditional weather forecasting signs of droughts, rains and floods. The traditional forecasters were asked their perception of traditional weather forecasting and changes in reliability and any aspect hindering its usage. They were also asked to describe how the traditional weather forecasting influenced their decision-making in planning for different climatic conditions.

3.5.2. Key informant interviews with agro-pastoralists

Like SSI, KII were translated into Setswana. Key informant interviews were administered using a guide (Appendix 2) to further explore the findings from both the FGD and SSI with key informants through in-depth discussions. Only adult and elder traditional weather forecasters knowledgeable about numerous indicators of traditional weather forecasting were purposively selected. The snowballing technique was used to select the key informants based on their participation and availability. From the semi-structured interviews and focus group discussions, participants recommended some of the traditional weather forecasters with whom the researcher engaged. KII were asked to describe the traditional weather forecasting indicators in depth, observed changes in the indicators during the time they have engaged with traditional weather forecasting and how the traditional weather forecasting is used to inform agro-pastoralism with the current prolonged drought in the area. The question posed regarding the change was flexible to allow the interviewees to indicate what they could remember.

3.5.3. Focus group discussions with agro-pastoralists

The focus group discussions were drawn from villages where the extension officers and farmers committees were able to recruit a number of participants at a go. Focus group discussions were organised strategically to ensure participants were disaggregated by gender and age to ensure that the data was specific to each group. Questions for the focus group discussion were derived from the semi-structured interviews guide to corroborate the data from the SSI. Based on availability of participants, six focus group discussions were conducted with each social class, namely: female youth, male youth, female adults, female elders and male elders (there were not enough adult males with whom to conduct a focus group). The focus groups were purposively selected in according to age and gender to ensure that each social group indicates the knowledge held by the specific group. However, the number of participants ranged from three to eleven participants, depending on availability of participants in each age and gender groups. The questions discussed included the different indicators used in traditional weather forecasting for rainfall patterns and any other climatic conditions. The participants were also asked to describe any changes that they have noted these indicators.

3.6. Data Analysis

All interview audio recordings were documented on Excel and were supplemented with field notes made during data collection. The audio recordings made up the qualitative data derived from the focus group discussions and semi-structured interviews. This qualitative data was subjected to content analysis whereas quantitative data was analysed descriptively to generate descriptive statistics such as percentages. Thematic analysis was used to identify themes and patterns of the qualitative data sets. Thematic analysis is a systematised approach using qualitative data to extract themes that relate to the research question (Attride-Stirling, 2001). From the audiotapes, the patterns of techniques and indicators were listed and a selection of direct quotations (quotes extracted from interview, focus groups and activity notes) and a few paraphrased ideas were grouped together (Aronson, 1995). These themes included rainfall quality (for food production), onset of rainfall, reliability of the different indicators used, threats on the indicators and usage in decision-making for agro-pastoralists. In addition, the descriptive statistics were used to group the occurrence data, which was synthesised in Excel to compare the differences among the social groups. The data sets were then analysed and presented using descriptive statistics such as frequency counts and percentages showing the proportions of respondents to a particular question.

After thematic analysis, the species and other indicators were translated to their scientific name. Heath and Heath, (2009) and Setshogo and Venter (2003) were used to translate the local names to scientific names for the plant species, whereas Hancock and Weiersbye (2015) and Senyatso (2005) were used to translate the bird species' names. However, during translation, other local names had different scientific names, which were all documented in this thesis.

3.7. Limitations of the study

Although the selection process aimed at recruiting participants from the farming community in the Bobirwa sub-district, failure to inform the interviewees well in time constrained the findings of this study. During the interviews, the respondents indicated that they had forgotten some of the indicators. Judging from not giving them enough time to reflect on the different indicators was limited to what they could think of immediately. Also, when translating the Setswana names identified during interviews, there is a possibility of misinterpretation of data owing to naming of species. Also, different common names/local names could be used to mean one species.

3.8. Ethical consideration

The research was conducted in accordance with the University of Cape Town ethical requirements. Interviewees' consent was gained by reading out the consent form for those who could not read, prior to conducting interviews This study was framed as an academic exercise and as such, the researcher does not predict any exposure of the research participants to any form of harm. Permission was gained to audio-record the interview and only the age and gender of respondents were used to identify the audios, to maintain anonymity.

3.9. Summary

The purpose of this review was to view trends in studies that work on traditional weather forecasting and to help the reader understand different indicators posed in other areas of research. This is significant because different agro-pastoralists have different approaches to generating traditional weather forecasts and have different coping strategies related to predicted weather extremes. There has been much research and discussion conducted on these approaches, including different indicator changes that forecasters have observed. However, very few studies have been directed at traditional weather forecasting and coping strategies of the youth and adults, who display limited knowledge, yet encouraged to be involved in agriculture. This leaves a wide gap in this field of research. Studying the views of agro-pastoralists of different gender and age groups would be interesting and crucial, especially if it would result in increasing resilience and improving agricultural policies.

Chapter 4

Results and discussions

4.1 Agro-pastoralists and their livelihood in Bobirwa sub-district

The sample population in this study encompassed agro-pastoralists who may or may not use traditional weather forecasting to adjust their activities and land management practices to mitigate impacts of climate variability; and also determining the perceived barriers to the use of this knowledge and to determine whether agro-pastoralists still find it reliable. A total of 101 agro-pastoralists were drawn from eight villages in Bobirwa. The respondents were categorised by age into three groups, namely youth (21-35), adults (36-64) and elders (65+), and by gender: male and female. SSI analysis revealed that the majority of respondents 34 of total interviewees were females (62%), of which 1 of the 34 total females (3%) were youth, 21 of 34 females (62%) were adults and 13 of 36 (36%) were elders. The total interviewees that participated in SSI, 21 of 55 (39%) were males from which, 1 of 21 (5%) male interviewees were youth, 3 of 21(14%) adults and 17 of 21 males (81%) were elders (Table 5). From the SSI, 16 of 21 (76%) of male participants were forecasters and18 of 34 (53%) of participating females were actively engaged in traditional weather forecasting, hence they were selected as the forecasters. It is depicted that the number of non-forecasters who use indirectly use traditional weather forecasting outweighs the number of non-forecasters who indicate to not depend on traditional weather forecasting for agro-pastoral activities. Within the different gender and age groups, semi-structured interviews and focus group discussions were conducted. Derived from semi-structured interviews, Table 5 presents demographic characteristics of 54 agro-pastoralists that indicated being active traditional weather forecasters. The agro-pastoralists in this study were predominantly smallholder farmers, with 98 of 101 (97%) of the respondents engaged in dry-land crop production, 93 of 98 (95%) producing at a subsistence scale and 5 of 98 (5%) mainly growing for commercial purposes, both using traditional rain-fed farming systems (Table 5).. Of the agro-pastoralists involved in crop production (i.e. sorghum, maize, millet, cowpeas, melon, groundnuts and beans), 76 of 98 (78%) owned at least one type of livestock, such as goats, sheep, cattle, donkeys and chicken. Only 3 of 101 (3%) of the respondents solely engaged in dry land communal livestock farming for the purpose of selling to generate income to sustain themselves. According to the agro-pastoralists, livestock rearing is considered to be an important aspect of life. The data indicate that youth (21-35) and adult males (36-64) are less actively involved in agro-pastoralism in the villages within the study area. More respondents were adult females because most male adults often look for alternative forms of formal work while women engage more in agro-pastoralism. However, elderly men indicate to be more active in agro-pastoralism than adult males. Findings of this study are similar to other studies that reveal that women engage more in agro-pastoralism than men, which is similar to the findings of this study (Olove et al., 2010). Lastly, there were diversified sources of livelihoods with 73 of 101 (72%) engaging in non-farm activities such as engaging in poverty eradication programmes such as *namolaleuba*, *mophane* harvesting and wild fruit harvesting. However, the participants identified rainfall to be crucial and indicate that each livelihood option faces risks associated with weather forecasting. The results suggest that vulnerabilities of the gender and age groups will be different, judging from the differences in participation in agro-pastoralism.

Table 5: Total percentage of respondents in each village within the Bobirwa sub-district

	Respondents in different villages in Bobirwa sub-district [b]							
Demographic variable [a]	Bobonong n= (1)	Moletemane n= (2)	Gobajango n= (7)	Molalatau n= (9)	Semolale n= (7)	Motlhabaneng n= (3)	Tsetsebjwe n= (9)	Mathathane n= (6)
Age in years								
21-35	0	0	2	0	0	0	2	2
36-64	9	2	2	7	2	2	11	6
65+	11	2	9	9	11	4	4	4
Gender								
Male	9	2	4	9	6	0	4	4
Female	11	2	9	7	7	6	13	7
Level of usage								
Non-forecasters and non-believers	0	0	6	2	2	2	0	0
Non-forecasters and believers	4	0	2	11	2	0	6	7
Forecasters and believers	17	4	6	4	9	4	11	4
Farming method								
Agro-pastoralism	20	4	6	13	13	4	9	9
Pastoral	0	0	2	0	0	0	0	1
Agronomy	0	0	6	4	0	2	7	0

[a] Socio- characteristics of agro-pastoralists and their livelihood option; [b] where the participants reside

4.2 Traditional weather forecasting in Bobirwa sub-district by different social groups

Focus group, semi-structured and key-informant interview participants indicated that traditional weather forecasting is attributed to respect for the environment and beliefs in spirituality. These beliefs are used to guide and support decision making by generating early warning signs using traditional weather forecasting and coping strategies. From the study area, the participating agro-pastoralists expressed traditional weather forecasting as a trustworthy method of reducing impacts of extreme weather events on agro-pastoralism productivity. This traditional weather forecasting has proven to be effective when executed appropriately and the agro-pastoralists express that they get positive feedback in terms of mitigating risks related to weather events. Interviewees further indicated that this knowledge has been used by many generations before and that it is important to adhere to certain beliefs and practices to achieve the good yields in weather constrained seasons. Surveys of traditional weather forecasting identified that weather forecasters in the study area depend on almost similar indicators to predict for the upcoming season. Traditional weather forecasting was grouped based on the indicators, namely: plant phenology, behaviour of birds, insects, amphibians and mammals, astronomical cues, clouds and wind. The indicators were further grouped into type of weather forecast that agro-pastoralists predict for: rainfall onset (forecasting upcoming rainfall within a few days or weeks), late rainfall, good rains (enough to produce substantial food and improve pastures), and little rainfall. Below are the indicators that agro-pastoralists use to predict the occurrence of adverse weather conditions such as droughts, floods, good rainfall.

4.3 Indicators used by agro-pastoralists for traditional weather forecasting

From the sample population, there were forecasters and non-forecasters who rely or were strongly against the use of traditional weather forecasting for generating early warning signs for drought and flooding. In this section, semi-structured interviews and focus group discussion were used to understand the tools that are used by agro-pastoralists in the Bobirwa sub-district to identify different indicators used in traditional weather forecasting. For the non-forecasters, who were not fully competent were asked, to what extent they know indicators used in weather forecasting. The study found that the agro-pastoralists have traditional weather forecasting based on local environmental, astronomical, biological and mythical indicators (Table 6 - Table 10). The indicators are used in different combinations depending on the location and individuals' experience with the interaction with the environment. KII were also used to elaborate on indicators identified in FGD and SSI.

4.3.1 Plant phenology as an indicator of traditional weather forecasting

During the focus group discussions and semi-structured interviews, it was noted that agro-pastoralists of the Bobirwa district use 11 plant species in their weather forecasting. Plant phenology such as significant flowering was mentioned by 23 of 37 (73%) of total forecasters from the sample population interviewed. Other phenological attributes included significant fruiting, mentioned by 7 of 37 (18%) of the forecasters, early flowering, mentioned by 10 of the 37 (27%) of the forecasters, leaves sprouting, mentioned by 3 of 37 (9%) of the forecasters, flowers dropping before the rainfall season starts mentioned by 3 of 37 (9%) of interviewees, seed pods splitting before rainfall season starts 3 of 37 (9%) and failure to lose leaves in winter mentioned by 5 of 37 (13%) interviewees have been reported by agro-pastoralists to forecast the weather patterns. Table 1 indicates the phenology of the identified species used to indicate the onset of rains, quality of the season and signs of an upcoming drought.

Findings of this study indicate that when *Acacia tortilis, Colophospermum mopane, Boscia albitrunca, Philenoptera violacea* flower in volumes between July and September, agro-pastoralists use these signs to determine the expected rainfall depending on the plant species Table 6. The most commonly used plants for traditional weather forecasting among Bobirwa agro-pastoralists are *Acacia tortilis* and *Colophospermum mopane* by all age and gender groups. The selected agro-pastoralists indicate that trees such as the *Boscia albitrunca* do not occur in all the villages in Bobirwa sub-district, therefore its usage is limited by geographical constraints (Table 6). Another plant phenology indicator that the interviewees mentioned is when the plants do not lose their leaves in winter, it is a sign that the upcoming season will have adequate rainfall.

Table 6: Plant phenology indicators for weather forecasting used by by elderly males (EM; n=13), adult males (AM; n= 2), elderly females (EF; n=9) and adult females (AF; n=13) and mentioned in semi-structured interviews and Focus Group Discussions (FGDs; n=6) in Bobirwa sub-district

Local name	**Scientific name**	**The sign in relation to rain [a]**	**The month indicators are observed**	**Total number of respondents of interviews (n=37)**		**FGD's (n=6)**
Mosu	*Acacia tortilis*	Significant flowering indicates that there will be limited rainfall. "Mosu o thuntse thata, o dirile dithunya tse ditshweu o itse gore ke ngwaga wa tlala."	Flowering in August	E;M (13)	6 (46%)	2
				A;M (2)	1 (50%)	-
				E;F (9)	2 (22%)	2
				A;F (13)	4 (15%)	2
				Total	13	6
Mophane	*Colophospermum mopane*	Significant flowering and fruit production of Mophane is an indicator of scarce rains. "Fa o ka bona Mophane o thunya, o nna le bana ba ba nnye, o itse gore ke ngwaga wa tlala, pula e tla na fale le fale."	Flowering in August	E;M (13)	2 (15%)	2
				A;M (2)	2(100%)	-
				E;F (9)	2 (22%)	2
				A;F (13)	2 (15%)	2
				Total	8	6
Motlopi	*Boscia albitrunca*	Significant flowering and fruiting signifies abundant rainfall. "Fa setlhare sa Motlopi se thunya, se nna le bana, se supa gore ngwaga o monamagadi."	Flowering in June/ July	E;M (13)	2 (15%)	2
				A;M(2)	0 (0%)	-
				E;F (9)	3 (33%)	2
				A;F(13)	2 (15%)	2
				Total	7	6
Mokanathitwa	*	Significant flowering is an indicator of abundant rain in the upcoming season. "Gase thunya, re itse gore dipaka di tsamaile, pula e setse e le gautshwane le gore pula e teng."	Flowering in July/ August	E;M (13)	1 (8%)	2
				A;M (2)	1 (50%)	-
				E;F (9)	0 (0%)	1
				A;F (13)	1 (8%)	1
				Total	3	3
Setlhaba tshukudu	*	Significant early flowering is an indicator of the onset of	Flowering in July	E;M (13)	2 (15%)	1
				A;M (2)	0 (0%)	-
				E;F (9)	0 (0%)	0

		rainfall and a good season ahead. “Se kaa gore pula e tla seola mo ngwageng oo, fa o se bona se thuntse thata."		A;F (13)	0 (0%)	1
				Total	2	2
Lepokole	*	Significant flowering indicates that there will be scarce rainfall. “Fa se thunya thata se kaa gore ngwaga oo re tla kgora.”	Flowering in September	E;M (13)	1 (8%)	1
				A;M (2)	0 (0%)	-
				E;F (9)	2 (22%)	2
				A;F (13)	0 (0%)	1
				Total	3	4
Mmatla	*Philenoptera violacea*	When the flowers drop before the rains start, it’s a sign that the rains will be late in that season. “O dira dithuna, mme fa o ka bona dithunya di wela fa fatshe, pula e ise e ne, o itse gore pula e thari."	Flowering in September	E;M (13)	2 (15%)	1
				A;M(2)	0 (0%)	-
				E;F (9)	1 (11%)	0
				A;F (13)	0 (0%)	0
				Total	3	1
Mhata	*Philenoptera violacea formerly: (Lonchocarpus capassa)*	When the seed pods split before it rains, it indicates that there will be low rainfall. “Fa bana ba Mhata ba thathologa pele pula e tsheola, o tlhoboge, pula ya teng e nnye).	Flowering in September	E;M (13)	1 (8%)	1
				A;M (2)	0 (0%)	-
				E;F (9)	2 (22%)	1
				A;F (13)	0 (0%)	1
				Total	3	3
Letlhokotso	*	Early flowering indicates abundant rainfall and good bean harvests. “Fa Letlhokotso le thunya ka kgwedi ya Phukwi, ke ngwaga wa dinawa”	Flowering in July	E;M (13)	1 (8%)	0
				A;M (2)	0 (0%)	-
				E;F (9)	1 (11%)	1
				A;F (13)	0 (0%)	0
				Total	2	1
Setlhaba kolobe	*Acanthospermum hispidum/ Bidens biternata/ Bidens schimperi*	Significant flowering towards the end of winter (deemed early flowering) is an indicator of good rainfall. “Setlhaba kolobe fa se thunya pele, fela jaaka re tswa mo marigeng jaana, re itse gore ke ngwaga ya kgoro, re tla sela sengwenyana”	Flowering end of June-beginning of July.	E;M (13)	1 (8%)	1
				A;M (2)	0 (0%)	-
				E;F (9)	0 (0%)	0
				A;F (13)	0 (0%)	1
				Total	1	2
Motsiara	*Combretum hereroense*	Abundant flowering and leaf sprout indicates good rainfall. “Fa o bona Motsiara o thunya, e bile o tlhoga	Flowering in September	E;M (13)	0 (0%)	1
				A;M (2)	0 (0%)	-
				E;F (9)	1 (8%)	1
				A;F(13)	0 (0%)	1
				Total	1	3

		matlhare, re itse gore pula e tla nna teng, ke ngwaga wa kgoro."				

Values presented are the number of respondents that use the indicators where n= 37. [a]= both English and Local or *Sebirwa* saying in quotes. *= Species that were not translated to Latin names.

The findings of this study are in agreement with findings of other studies that show plant phenology, i.e. flowering, fruiting, etc., are used in different traditions to forecast weather rainfall (Kolawole et al., 2014a). In accordance with plant phenology, phenotypic responses are influenced by levels of humidity in the atmosphere and temperature, as indicated in various studies (Laube et al., 2014; Fernandes et al., 2015). In instances when there are changes in seasonal temperature and humidity, the traditional seasonal forecasters are able to forecast for the upcoming season using these changes in plant phenology. Flowering plants at the end of winter are regarded as markers of the rainy season. *Acacia* plants, for example, are documented to flower at the end of winter and are expected to flower with the change in humidity, temperature and wind (Sekhwela and Yates, 2007). These phenotypic changes are attributed to changes in temperature, wind speed and humidity (Elzinga et al., 2007). However, the extent of flowering of certain species are said to express the amount of rainfall expected in a season. The non-forecasters of the traditional weather forecasting indicate awareness of the use of flowering in predicting for rain and drought seasons and are familiar with the three most common plants used in predicting for drought and good rainfall. These three plants are very common plants in the Bobirwa sub-district; hence were more predominant among the agro-pastoralists. Plant phenology tends to be used more as good indicators of an upcoming drought. A study by McDowel et al. (2011) states that vegetation types' response to drought as outlined by the agro-pastoralists correlates to plant responses to water deficits. Similar to this study in Southern Africa, leafing, flowering and fruiting of *Acacia tortilis* and *Colophospermum mopane* have been reported to be common in determining the drought season. Yet, the extent of flowering and its timing correspond to atmospheric pressure, which reflects the humidity content in the atmosphere. At high humidity, some *Acacia* spp. generate few flowers, whereas at low humidity they generate more flowers. A study by Kozlowski and Pallardy, (2002) conforms to findings in this study that plants tend to flower as an indicator of drought. Hence, this plant is considered a good indicator of the preceding season owing to its response to changes in atmospheric humidity and temperature. In a study by Stevens et al., (2016), it is indicated that plant species in the arid savanna are predominantly influenced by the soil moisture, which determines the deciduousness of the plant. During seasons when the soil moisture is high, the plants stay green and the agro-pastoralists use this as a cue of increased soil moisture. As identified by forecasters deciduous plants that do not lose leaves in winter are used are used as a sign of good rains in upcoming spring/summer seasons.

4.3.2 Birds as indicators of traditional weather forecasting among different social groups

Agro-pastoralists of the Bobirwa sub-district use seven birds to forecast the upcoming trends of the season. From the pastoralists' responses, 21 of 37 (57%) forecasters identified that birds are critical in predetermining the quality of rainfall, forecasting the onset of rainfall, early rainfall and drought (Table 7). The behaviour that is most noted with these birds includes the birds singing in a particular way mentioned by 19 of 37 (51%) forecasters, ruffling of feathers mentioned by 2 of 37 (5%) forecasters and their actual presence 15 of 37 (41%) forecasters, which are used to forecast weather. The commonly used birds for a good rainfall season include *Bucorvus leadbeateri*, *Ciconia abdimii*, *C. ciconia* and *Merops nubicoides*, whereas *Tachymarptis melba/Hirundo fuligula* is the most common bird that signifies the onset of rainfall.

Findings of the study show that all the seven bird species are mostly used by elders; however, the most predominant group that use the birds are the elderly males. The birds are generally identified as reliable by all the different groups: 19 of 21 (90%) of non-forecasters of traditional weather forecasting reported being aware of the use of birds in weather forecasting by the elders. Generally, the use of birds as indicators is more predominant among elderly males (63%) than any other group (Table 7). The findings of this study also indicate that the overall use of birds is more common among men than women. From the interviews, one farmer indicated that the some of the birds are observed in dusky areas further away from the homesteads. Therefore, it may be the reason why less women use these birds, as their duties are around the homestead. To a lesser extent, the use of birds as indicators is less common among the adults. 2 of 13 (15%) adult females are less knowledgeable of *Bucorvus leadbeateri*, 1 of 13 (8%) *Ciconia abdimii/C. ciconia*, 1 of 13 (8%) *Merops nubicoides* and 1 of 13 (8%) *Hirundo fuligula* (Table 7). Additionally, in the semi-structured interviews, there was no mention of the use of *Buteo vulpinus*, *Ardeotis kori* and *Mmamphuphane* by adults; however, they were mentioned in focus group discussions (Table 7). Adults do not use birds for forecasting as they expressed having limited knowledge on these of indicators.

Table 7: Birds as indicators for weather forecasting used by elderly males (EM; n=13), adult males (AM; n= 2), elderly females (EF; n=9) and adult females (AF; n=13) and mentioned in semi-structured interviews (n=37) and Focus Group Discussions (FGDs; n=6) in Bobirwa sub-district

Local name	**Scientific name**	**Sign in relation to rain [a]**	**The month indicators are observed**	**Total number of interview respondents (n=37)**		**FDG'S**
Lehututu	*Bucorvus leadbeateri*	When these birds sing out loud, it is an indication of good rainfall and that the rainfall will be early. "Mahututu a mantsho fa a lela ka go fapaana phakela le maetsiboa, a kaa pula, le gore pula e tla na ka pele.	Expected to be seen and heard in July.	E;M (13)	5 (38%)	2
				A;M (2)	1 (50%)	-
				E;F (9)	3 (33%)	2
				A;F (13)	2 (15%)	2
				Total	**11**	**6**
Makololwane	*Ciconia abdimii (Black)* and *Ciconia ciconia (White)*	The presences of flocks of these birds are indications of good rainfall but when they are a few, it is an indication of scarce rainfall.	Observed in September	E;M (13)	5 (38%)	2
				A;M (2)	0 (0%)	-
				E;F (9)	2 (22%)	2
				A;F (13)	1 (8%)	1

		"Makololwane ga a tswe mo garona, mme fa a goroga, a kala, re itse gore pula e tla nna teng"		**Total**	**8**	**5**
Peolwane	*Tachymarptis melba/ Hirundo fuligula*	Presence of Peolwane are an indicator of the onset of rainfall. "Dipeolwana fa di kala, di kaa gore pula e ka nna ya nna teng"	Observed in September/ October	E;M (13)	4 (31%)	2
				A;M (2)	0 (0%)	-
				E;F (9)	2 (22%)	2
				A;F (13)	1(8%)	2
				Total	**7**	**6**
Morokapula	*Merops nubicoides*	Flocks of this bird singing out loud indicate there will be a good rainfall season. "Fa Morokapula o dirile phuthego o lela thata, letsatsi le tserema, ke sekao sa gore pula e tla nna teng."	Observed in September	E;M (13)	4 (31%)	2
				A;M (2)	0 (0%)	-
				E;F (9)	2 (22%)	2
				A;F (13)	1 (8%)	2
				Total	**7**	**6**
Mankgodi	*Buteo vulpinus*	When a flock of these birds sing out loud, it's an indication of the onset of the rains. "Fa boNkgodi ba nna bantsi e bo di sa kale thata, gantsi ba pagama setlhare e bo ba lepeletsa diphuka, ba lela ka molelo o le mongwe di lela re itse gore pula e teng."	Observed in September to October	E;M (13)	2 (15%)	2
				A;M (2)	0 (0%)	-
				E;F (9)	1 (11%)	2
				A;F (13)	0 (0%)	1
				Total	**3**	**5**
Kgori	*Ardeotis kori*	When flocks of Kgori ruffle their feathers simulating the sounds of thunder it is an indication of good rainfall in the upcoming planting season. "Fa boKgori ba tsholetsa diphuka e bo e dira moduma o e kareng pula e duma, pula e tla nna ntsi"	Observed in September	E;M (13)	1 (8%)	1
				A;M (2)	0 (0%)	-
				E;F (9)	1 (11%)	2
				A;F (13)	0 (0%)	2
				Total	**2**	**5**
Mmamphuphane	*	Singing in the evenings signifies the onset of rainfall. "Fa e nna fa batshe ka letlatlana, e bo e lela, o itse gore pula e a goroga."	Signing in the evening in September	E;M (13)	1 (8%)	1
				A;M (2)	0 (0%)	-
				E;F (9)	0 (0%)	1
				A;F (13)	0 (0%)	1
				Total	**1**	**3**

Values presented are the number of respondents that use the indicators where n= 37.[a]= both English and Local or Sebirwa saying in quotes. *= Species that were not translated to Latin names.

Similar to the findings of this study, the appearance of *Hirundo smitihii* in large numbers is used to signify the onset of rainfall in Tanzania (Elia et al., 2014). Likewise, appearance of migratory birds in Kenya (Kagunyu et al., 2016) is used in forecasting upcoming rainfall patterns. Certain birds singing in Uganda (Okonya and Kroschel, 2013), Tanzania (Elia et al., 2014; Chengula and Nyambo, 2016), Zimbabwe (Soropa et al., 2015), are used to indicate good seasonal rainfall. Birds such as the *Bucorvus* sp which the Bobirwa agro-pastoralists use, has been also identified to be used the same way in Uganda (Orlove et al., 2010). As explained in the literature review, it was identified that birds react to changes in atmospheric pressure, thus their behaviour reflects changes in weather patterns. Studies indicate that bird migration, breeding and behaviour are influenced by temperature, humidity and photoperiods (Russell et al., 2014). The migratory birds in this study, including *Hirundo smitihii*, *Bucorvus leadbeateri*, are categorised as endangered or vulnerable to extinction, according to the International Union for Conservation of Nature (IUCN) Red data list of threatened species (2010); Chiweshe, (2005) and BirdLife International. (2016). As a result of climate change impacts and limited conservation efforts, these species could be extinct, consequently leading to agro-pastoralists'/individuals' lack of faith in the indicators as the indicators they are familiar with will not be present to make weather forecasting.

4.3.3 Insects, amphibians and mammals as indicators of traditional weather forecasting among different social groups

The findings of the study in the Bobirwa sub-district further indicate that insects, amphibians and mammals are used as indicators of weather. To begin with, specific insect species were identified by agro-pastoralists to exhibit characteristics that are associated with traditional weather forecasting. Both interviews and FGDs revealed that the most common insects that are used most often for weather forecasting in the Bobirwa sub-district are ants, termites, white butterflies and grasshoppers. The agro-pastoralists specifically consider the behaviour of ants, termites, grasshoppers and the appearance of an influx of butterflies as a sign for the forthcoming rains. The main insects used for determining the quality of seasonal rainfall include white butterflies and *Makeke*, whereas *Bonyonyo* is common for determining the onset of rainfall (Table 8). The use of insects is mostly common among both male and female elders, with less usage by adult agro-pastoralists. From the interviews, it is identified that white butterflies, *Bonyonyo*, termites are used only by elders (Table 8). Findings of this study further indicate that agro-pastoralists of the Bobirwa sub-district use the behaviour of insects to predict good or bad seasonal rainfall, termites, ants and butterflies are examples of used in that regard. Use of amphibians is another form of traditional weather forecasting indicator – specifically, croaking of frogs, which 18 of 37 (49%) of the interviewees highlight they use to predict the onset of rainfall (Table 8). It further indicates that 6 of 9 (67%) of the elderly women use the croaking frog, while the elderly male 5 of 13 (38%). Lastly, FGD's, KII and SSI identified the use of mammalian species as indicators of traditional weather information. Particular to Bobirwa sub-district, *Procavia capensis* was identified by 16 of 37 (43%) of the participating agro-pastoralist respondents (Table 8). Use of the rock rabbit as an indicator for imminent rainfall is common among 6 of 13 (46%) among both male elders and female adults, yet elderly women do not commonly use it.

Table 8: The behaviour of insects, amphibians and mammals as indicators for weather forecasting used by elderly males (EM; n=13), adult males (AM; n= 2), elderly females (EF; n=9) and adult females (AF; n=13) and mentioned in semi-structured interviews (n=37) and Focus Group Discussions (FGDs; n=6) in Bobirwa sub-district

Local name	Common name	Sign in relation to rain	The month indicators are observed	Total number of respondents (n=37)		FG Ds
Insects						
Dirurubele tse di tshweu	White butterflies	The appearance of migratory white butterflies flying from West to East is a good sign that the rainfall will be adequate for a good harvest. They also indicate the onset of the rainfall because once they pass, then it takes up to seven days for the rain to fall. "Fa o ka bona Dirurubele di fofa ka dipalo, di tswa Botlhaba tsatsi	September into Observed in October	E;M (13)	6 (46%)	2
				A;M (2)	0 (0%)	-
				E;F (9)	5 (56%)	2
				A;F (13)	0 (0%)	2
				Total	**11**	**6**
Makeke	*	When they start harvesting food into their nests, it is an indication that there will be good rains. It also indicates the onset of rainfall within a few days. "Fa o bona Makeke a tlwaafaletse go kuka Bojwang, a isa ko mosimeng, re itse gore pula e gaufi, e bile e tla nna ntsi. Fa a dira jaana, rea re a rurela, a ipaakanyetsa pula."	Observed in October	E;M (13)	2 (15%)	2
				A;M (2)	1 (50%)	-
				E;F (9)	1 (11%)	2
				A;F (13)	1 (8%)	2
				Total	**5**	**6**
Bonyonyo	*	The appearances of *Bonyonyo* indicate that rains in that season are imminent. "Fa go na le *Bonyonyo* bo le bontsi, pula e tla nna ntsi. "	Observed in August-September	E;M (13)	1 (8%)	2
				A;M(2)	0 (0%)	-
				E;F (9)	2 (22%)	2
				A;F (13)	0 (0%)	1
				Total	**3**	**5**
Motlhwa	Termites	When termites start building their nests, it is an indication of the onset of the rainfall. "Gao agela ko godimo, re itse gore pula e gautshwane."	Observed in September/ October	E;M (13)	1 (8%)	2
				A;M (2)	0 (0%)	-
				E;F (9)	1 (11%)	1
				A;F (13)	0 (0%)	1
				Total	**2**	**3**
Dishiane	*	The appearance of these ants in large numbers signifies that there will be good rains and plenty of sorghum harvest. "Ga ditswa di nna dintsi, o bo o itse gore pula e teng, re tla bolaya mabele."	Observed in September	E;M (13)	2 (15%)	2
				A;M (2)	0 (0%)	-
				E;F (9)	0 (0%)	1
				A;F (13)	0 (0%)	1
				Total	**2**	**4**
Dingaingai	*	The appearance in large numbers indicates that there will be adequate rainfall. "Gao di bona, o itse gore pula e tla nna teng."	Observed in October	E;M (13)	1 (8%)	1
				A;M (2)	0 (0%)	-
				E;F (9)	0 (0%)	0
				A;F (13)	0 (0%)	0
				Total	**1**	**1**
Amphibians						

Segogwane se se sweu	White Frog	When frogs croak during a hot sunny day, it indicates near rainfall onset. The frogs are often white, if one gets to see them. Fa o utlwa *Segogwane* se lela go le letsatsi le le fisang tota, re itse ogre pula e gaufi.	Observed during the rainfall season.	E;M (13)	5 (39%)	2
				A;M (2)	0 (0%)	-
				E;F (9)	6 (67%)	2
				A;F (13)	7 (54%)	2
				Total	**18**	**6**
Mammals						
Pela	*Procavia capensis*	When rock rabbits cry out in a certain way, it indicates the onset of rainfall. "Fa o ka utlwa pela e lela, o itse gore pula e gaufi. O ka ipaakanya.	During the rainfall season	E;M (13)	6 (46%)	1
				A;M (2)	1 (50%)	-
				E;F (9)	3 (33%)	2
				A;F (13)	6 (46%)	2
				Total	**16**	**5**

Values presented are the number of respondents that use the indicators where n= 37.[a]= both English and Local or Sebirwa saying in quotes. *= Species that were not translated to Latin names.

As elaborated in the literature review, insects, mammals and amphibians are used in generating traditional weather forecasting (Mogotsi et al., 2011, Zuma-Netshiukhwi et al., 2013; Elia et al., 2014; Kolawole et al.2014a). Firstly, indicators used in Bobirwa sub-district are in line with those of different studies that express the insects including termites and ants in Mexico (Rivero-Romero et al., 2016) and the Philippines (Galacgac and Balisacan, 2009). It has been established that insects are able to track weather patterns owing to their response to changes in atmospheric pressure. This is in conformity with Enjin et al. (2016), who suggest that insects such as *Drosophila* species are able to detect changes in humidity, which in this case are used as cues the agro-pastoralists use. Findings of this study showing *Makeke* as key indicators for heavy rainfall, are similar to a study in Accra (Codjoe et al., 2014), where ants carrying grass is used to signal heavy rainfall. It has been established in literature that forager ants tend to increase in number as the humidity increases as a mechanism for their survival (Gordon et al., 2013; Davidson et al., 2016). Pinter-Wollman et al. (2012) highlight that during dry seasons movement of the harvester ants is reduced. Owing to the attentiveness of individuals in rural areas, they have identified this foraging behaviour and associated it with rainfall. That is, more *Makeke* (harvester ants) will be observed as an indication for onset of rainfall and during drought seasons, there will be fewer ants observed, which the traditional forecasters have already established (Table 8). Secondly, to support findings of this study, it has been established that relative humidity and temperature influence habitat choice for most *Lepidoptera* species (butterflies and moths) (Molina-Martínez et al., 2016; Henderson et al., 2017). The current anthropogenic warming may pose threats to traditional forecasting cues which rely on humidity and temperature for their feeding, breeding and migration which communities/individual forecasters may not be able to account for (Higgin et al., 2014; Slancarova et al., 2016). For example, current threats of climate change on the habitats of butterfly and moth species may alter the availability of these indicators for traditional weather forecasters as these species relocate to more conducive areas for breeding (Andrew et al., 2013; Urban, 2015). To support this argument further, studies have shown that changes in the grasslands can potentially impact insect distribution. Moreover, this could potentially be a threat to the already accumulated traditional weather forecasting should newer observations be noted.

The findings of this study indicate that the agro-pastoralists use the appearance and croaking of frogs to predict the onset of rainfall. These findings are similar to those from Elia et al. (2014) and Roncoli et al. (2002), which show the appearance to frogs to be used to indicate the onset of rainfall. Recent analyses indicate that insects and animal species respond to temperatures which affect the breeding phase (Pellegrino et al., 2013). However, in instances where the conditions are not favorable to mass reproduction, the insects are fewer and therefore the agro-pastoralists see that as an indicator of drought.

4.3.4 Astronomical cues as indicators of traditional weather forecasting among different social groups

From the results, it was established that the predominantly used astronomical signs for traditional weather forecasting are from stars *Kopa dilalelo*18 of 37 (49%) *Pitso ya kgwedi* 15 of 37 (41%) and *Kgoro le tlala* 14 of 37(38%), as depicted in Table 9. Among elder and adult males, *Kopa dilalelo* is principal in predicting the quality of the rainfall, whereas elder females use *Kgoro* more (Table 9). The leading indicator used by adult females is the moon halo *(Pitso ya ngwedi*) (Table 9). Youth have indicated being aware of these common indicators which they do not actively use themselves.

Table 9: Use of astronomical cues to forecast rainfall by elderly males (EM; n=13), adult males (AM; n= 2), elderly females (EF; n=9) and adult females (AF; n=13) and mentioned in semi-structured interviews (n=37) and Focus Group Discussions (FGDs; n=6) in Bobirwa sub-district

Local name	Sign in relation to rain [a]	When it is expected to appear	Total number of interview respondents (n=37)		FGDs
Kopa dilalelo	The emergence of the *Kopa dilalelo* starts from east following a path towards the west If this star is visible throughout the season it assures agro-pastoralists of good rainfall. However, if there is a slight deviation in its position or path, then the rains will be scarce. "E nna ka fa bophirima. E kotama ka kgwedi ya Phatwe, e bo e nna e tlhatlhoga e tlhamaletse. Re itse gore ngwao oo ke oo siameng."	From September until the end of the planting season	E;M (13)	7 (54%)	2
			A;M (2)	2 (100%)	-
			E;F (9)	6 (67%)	2
			A;F (13)	3 (23%)	2
			Total	**18**	**6**
Kgoro le tlala	A cluster of stars forms what is visible as two brownish clouds in the sky. The positioning and size of the two clusters of stars indicates either scarce rainfall or good rainfall. "E ka re lerunyana le le nnelalang ka fa thalatara sefalatalaKgoro e nna e le tona, tlala e le nnye."	From September to November	E;M (13)	4 (31%)	2
			A;M (2)	0 (0%)	-
			E;F (9)	7 (78%)	2
			A;F (13)	3 (23%)	2
			Total	**14**	**6**
Pitso ya kgwedi	When the moon is surrounded by a round circle, it indicates that there is ample water for a good season.	Around August before the season starts	E;M (13)	5 (38%)	2
			A;M (2)	2 (100%)	-
			E;F (9)	5 (56%)	2

	“Fa ngwedi o ntshetsi pitso, pula e tla nna tengmme pula ya teng e kgakala”		A;F (13)	3 (23%)	2
			Total	**15**	**6**
Selemela	This star is visible from the east and travels towards the west. This indicator often works hand in hand with Kopa dilalelo. “Fa nako ya temo e tsamaile, re leba ka selemela. Se tla bo se sutile, se le ntlheng e sele.”	From July	E;M (13)	2 (15%)	2
			A;M (2)	0 (0%)	-
			E;F (9)	5 (56%)	2
			A;F (13)	0 (0%)	1
			Total	**8**	**5**
Phifalo ya ngwedi	The appearance of the eclipse of the moon indicates a good season. “Phifalo ya ngwedi e kaa gore pula e tla nna teng mme e le gaufi.”	October	E;M (13)	1 (8%)	1
			A;M (2)	2 (100%)	-
			E;F (9)	1 (11%)	1
			A;F (13)	2 (15%)	0
			Total	**6**	**2**
Mesi mo loaping (Leoto)	When the atmosphere appears to be saturated with smoke when there is no fire anywhere, that is an indicator that the upcoming rainfall will be good. “Fa loapi le setlhafala go a bo go supafala gore metsi a mantis.”	From June to September	E;M (13)	1 (8%)	1
			A;M (2)	0 (0%)	-
			E;F (9)	2 (22%)	2
			A;F (13)	3 (23%)	2
			Total	**6**	**5**
Pitso ya letsatsi	When the sun halo is large, it is an indication that there will be good upcoming rainfall. However, when the halo is small, it is an indication that the rains will be sparse. “Pitso ga e le tona ke ngwaga wa pula, mme fa e le nnye, go tlala.”	August	E;M (13)	1 (8%)	2
			A;M (2)	1 (50%)	-
			E;F (9)	1 (11%)	1
			A;F (13)	2 (15%)	1
			Total	**5**	**4**
Phifalo ya letsatsi	The appearance of the solar eclipse is indicative of the onset of rainfall. " Letsi le kare le apere leru, go supa gore pula e gaufi"	During the rainy season	E;M (13)	1 (8%)	0
			A;M (2)	1 (50%)	-
			E;F (9)	1 (11%)	1
			A;F (13)	1 (8%)	0
			Total	**4**	**1**
Motshe wa badimo	The appearance of a complete rainbow indicates that the rain has permanently stopped for the day. Whereas if the rainbow appears to be incomplete, it’s a sign that the rain has temporarily stopped. "Fa motshe wa badimo o kgaoga, go kaa gore metsi a ne a emelela ko lewatleng a tla a le mantsi, go raya gore pula e tla santse e tswelela. Mme fa o felelela, go supa gore e kgaola pula.	When it rains	E;M (13)	2 (15%)	1
			A;M (2)	0 (0%)	-
			E;F (9)	0 (0%)	2
			A;F(13)	2 (15%)	2
			Total	**4**	**5**
Dikolobe le dintsa	The appearance of these stars in the west is an indication that there will be good rains in the upcoming season. “Fa di bonala ka fa bophirima tsatsi re itse gore ngwaga o dijo di tla nna teng. Mme fa di boela ka fa botlhaba tsatsi, di tsisa serame se se botlhoko.”	September	E;M (13)	1 (8%)	0
			A;M (2)	0 (0%)	-
			E;F (9)	2 (22%)	1
			A;F (13)	0 (0%)	1
			Total	**3**	**2**

Values presented are the number of respondents that use the indicators where n= 37.[a]= both English and Local or Sebirwa saying in quotes.

The perception of time among the locals is often noted with the rise of the moon and considered cyclical. Therefore, they use astronomical signs to manage time and also to predict the rainfall (Table 9). In using astronomical phenomena as indicators weather forecasting, the moon, stars and the rainbow are perceived to have high degree of reliability among the forecasters. A study in Ghana indicates similarities of forecasters using the rainbow, which symbolises end of the rainfall

(Codjoe et al., 2014). However, 2 of 15 (15%) elderly males and 2 of 15 (15%) female adults agro-pastoralists in the Bobirwa sub-district indicate further that the rainbow signals end of the rain when it is at 180 ° and when it is halved; it shows that there will be more rain (Table 9). The study found that agro-pastoralists in Bobirwa sub-district use astronomical cues in traditional weather forecasting. Stars and the moon are used extensively by agro-pastoralists to predict when rain can be expected. For instance, at certain times, the moon is observed to be in halo and in certain communities signifies the good rain in the upcoming season. These findings are in line with findings from South Africa (Zuma-Netshiukwi et al., 2013) and Zimbabwe (Shoko and Shoko, 2013). The agro-pastoralists also indicate that the changes in the shape and position and accordingly, also indicate the onset of rainfall. The analyses reveal that the stars are also observed as part of the weather forecast. In particular, agro-pastoralists observe the star constellation to forecast the onset of and the quality of rainfall. Studies by Zuma-Netshiukwi et al. (2013) and Elia et al. (2014) revealed that the appearance of a group of stars indicates the onset of rainfall and it is around this time that the agro-pastoralists start preparing seeds and soil for planting. The relationship between astronomy and rainfall is specialised and requires the know-how to predict successfully. The use of astronomical cues is more practiced among elders, who use constellation movements and lunar phases. A ring around the moon and sun (corona) occur as a result of refraction by which a beam of light spreads into the region behind an obstacle (Battan, 1979). The light waves from the moon become slightly bent to water droplets in the atmosphere, thereby creating a ring around the moon. It should be noted that the radius of the corona is inversely proportional to the size of the water droplets. Also, a study by Critchfield (1983) revealed that the moon and the sun shine through cirrus cloud types composed of ice crystals to form a halo. These changes in star and moon appearance have been recorded to occur from August to September, coinciding with the rainfall season for the area (Table 9). Indeed, other studies indicate that when a halo is large it shows that there will be a lot of rainfall, and a small halo signifies low rainfall, as in the case of the Bobirwa sub-district agro-pastoralists, and that from Zimbabwe (Shoko and Shoko, 2013), as true reflection of the amount of water in the atmosphere.

4.3.5 Clouds and wind as indicators of traditional weather forecasting among different social groups

In addition to astronomical cues, changes in atmospheric cues such as cloud and winds are used for traditional weather forecasting by agro-pastoralists in Bobirwa sub-district. The focus group discussions and semi-structured interviews reveal that the Bobirwa sub-district mostly experience cloud cover at the end of the dry season (winter), which is often associated with the beginning of the rainfall season. The appearance of clouds (Maru), the direction in which they travel, their colour and shape and movement, have been noted by the elders to be good indicators of the onset and the quality of rainfall for the season. Forecasters indicate that although cloud cover fluctuates during spring to summer seasons, they are able to distinguish between the different types of clouds. Non-forecasters, on the other hand, show little knowledge on differentiating and naming the types of clouds, so cannot generate much traditional weather information in this regard. Examples of clouds that were identified by forecasters are outlined in Table 10. If one of the cloud types, such as Maebela clouds, is visible as early as July, it indicates that the rains will not be late (Table 10). The presence of clouds locally named *kgaka* are observed from July, which can often appear during the rainy season, this is associated with determining weather information for the upcoming season (Table 10). Kgaka is used by 12 of 37 (32%) of these agro-pastoralists indicate that '*Kgaka'*, derived from the shape that forms patterns similar to that of the guinea fowl, indicates that there will be abundant rainfall (Table 10). However, if it is not there, then the rainfall may not be as abundant. The appearance of the *kgaka* is also associated with cold weather. According to the interviewees, cold winters are a sign of good rains in the upcoming season. Also, generated from the interviews it was identified that 6 of 37 (16%) of forecasters used *kapoko,* clouds that look like mist, which often form around the atmosphere, giving the surrounding a smoky look used as an indicator for imminent good rainfall (Table 10). Another type of cloud used as an indicator for traditional weather forecasting is the Cumulonimbus cloud, locally known as *Matlakadibe*, which is used by6 of the 11 of 37 (30%) agro-pastoralists (Table 10). The word *Matlakadibe* is used interchangeably for both the cloud, rain and the wind. These clouds are accompanied by thunderstorms, hence their association with winds and rainfall. *Matlakadibe* is associated with sparse rainfall but may result in flash flooding and heavy winds which tend to damage crops. Lastly, clouds identified by agro-pastoralists of the Bobirwa sub-district explained that clouds traveling from the south do not bring rainfall, as the locals express it saying *"Leru le le tswang borwa galena metsi, le fa pula ya teng e ka na. Mosadi gaa tswe borwa e se phefo."* Clouds traveling from the direction of Zimbabwe and Mozambique according to the forecasters are examples of cloud travel used to determine rainfall in Bobirwa sub-district.

Table 10: Use of clouds, wind direction as indicators for weather forecasting used by elderly males (EM; n=13), adult males (AM; n= 2), elderly females (EF; n=9) and adult females (AF; n=13) and mentioned in semi-structured interviews (n=37) and Focus Group Discussions (FGDs; n=6) in Bobirwa sub-district

Local name	**Sign in relation to rain [a]**	**When it is expected to appear**	**Total number of interview respondents (n=37)**		**FGDs (n=6)**
Kgaka	When it is seen, it indicates that the rainfall will be early and abundant, with a lot of 'Medupi' "Pula ya teng e na ka bonako, e tsisa medupe."	Visible in July and indicate that there will be adequate rainfall	E;M (13)	3 (23%)	1
			A;M (2)	2 (100%)	-
			E;F (9)	5 (56%)	2
			A;F (13)	2 (15%)	2
			Total	**12**	**5**
Matlakadibe	These clouds are associated with catastrophic events which cause damage to houses, breaking trees and crops and during the plant growing phase, they increase the evaporation rates in soils.	During the rainy season.	E;M (13)	4 (31%)	2
			A;M (2)	0 (0%)	-
			E;F (9)	4 (44%)	2
			A;F (13)	3 (23%)	1
			Total	**11**	**5**

	"Leru le, le tla ka diphefo, e bile le kgona gotla dijwalo di budule, e be e roba mabele e bo a wela mo metsing a bo a simolola go mela."				
Leru la Zimbabwe	The clouds come from the Zimbabwe side. It indicates that there will be 'Medupi'. "Leru le le tswa ka fa botlhaba, le tsisa pula e ntle. Fa le kala le bo le duma, re itse gore pula e tla na."	During the rainy season.	E;M (13)	3 (23%)	2
			A;M (2)	1 (50%)	-
			E;F (9)	2 (22%)	2
			A;F (13)	2 (15%)	2
			Total	**8**	**6**
Maebela	The clouds are deep grey and often bring silent rains that we need for the crops to do well. "Leru le, ga re le bona, re itse gore pula ya meduppe e tla goroga, ka key one e re e tlhokang gore dijwalo tsa rona di nonofe."	During the rainy season.	E;M (13)	3 (23%)	2
			A;M (2)	0 (0%)	-
			E;F (9)	3 (33%)	2
			A;F (13)	0 (0%)	1
			Total	**6**	**5**
Kapoko	When it is temperatures suddenly drop during spring and summer, its an indication of rainfall. "Fa serame se le sentsi, re itse gore pula e tla na."	During during September/ October	E;M (13)	3 (23%)	1
			A;M (2)	0 (0%)	-
			E;F (9)	3 (33%)	2
			A;F (13)	0 (0%)	2
			Total	**6**	**5**
Leru la Mozambique	This cloud travels from the Mozambique direction "Fa go ka emelela leru le, gale tsamaya sentle, o tla bona peolwane, le tsisa pula ya medupe e ekareng lefatshe le ka wela"	During the rainy season.	E;M (13)	2 (15%)	
			A;M (2)	0 (0%)	
			E;F (9)	1 (11%)	
			A;F (13)	0 (0%)	
			Total	**3**	

Values presented are the number of respondents that use the indicators where n= 37.[a]= both English and Local or Sebirwa saying in quotes.

The seasonal movements of agro-pastoralists in the study area often observe the movement of winds and clouds to determine the onset and quality of rainfall. For example, the agro-pastoralists use cloud colour and the direction of travel of both the wind and clouds to determine the onset of rainfall. These results are similar to findings in studies from Uganda (Orlove et al., 2010), South Africa (Zuma-Netshiukwi et al., 2013). Multiple whirlwinds that are soft and frequent in at the end of winter season July are understood to cause good rainfall in the eminent season. In contrast, when there are no whirlwinds or very few, it is an indication that there will be erratic rainfall. The results of this study are similar to findings in Zimbabwe that show that whirlwinds experienced during August is an indication of good seasons (Muguti and Maphosa, 2012). From the interviews, it was established that the agro-pastoralists who spot any of the above-mentioned indicators are likely to share the early warning signs with their families (particularly the wife or husband), or fellow pastoralists during any form of gathering or interaction. It is a common practice to discuss the biotic and abiotic indicators to cross check and validate the traditional weather forecast information. Despite the differences in the ability to identify indicators by different gender groups, the final forecast on the expected rainfall is an integration of views from both gender groups and peers. However, diffusion of the information is restricted by age, as the knowledge indicates to be limited for adults and youth. Also, the perceptions of credibility among the agro-pastoralists influence the adoption of this traditional weather forecasting information. Lastly, beliefs of the agro-pastoralists in the Bobirwa sub-district are used to credit or discredit the traditional weather forecasting.

4.5 Gender-based and age difference use of traditional weather

There is a clear age- and gender-based difference in knowledge of various indicators and coping strategies to climate variability. FGDs and SSI indicate that gender roles often dictate how individuals spend their time and interact with the environment, which could account for the indicators that are used by different individuals Generally, the interviews depicted that adult forecasters use fewer indicators, compared to elders. For example, 55% of the overall plant phenology indicators identified in this study are only known and used by elders and adult forecasters do not use these for traditional weather forecasting (Table 6). Also, more males use plant phenology than women, as indicated in Table 6. Examples of the plants that men use more of include the *Acacia tortilis*, *Colophospermum mopane*, *Setlaba tshukudu* and *Mokanathitwa*. Boscia albitrunca (Motlopi) is more common as an indicator amongst women than males. This could be attributed to the fact that it bears wild fruits commonly harvested by females. However, attributing harvesting to be an enabler for knowledge on physiological changes in the plants, *Colophospermum mopane* (Mophane) contradicts this as more males use it mre than females do. It is established that roles of individuals influence the knowledge of forecasting and the ability to cope with climate variability. Despite the differences in knowledge, there are overlaps in the different roles by gender an age groups. In most sites, the male participants engaged in herding livestock (cattle, sheep and goats) while females engage in crop production (millet, sorghum, groundnuts, maize, cowpeas) and collecting fruits (mophane, morula, wild mushroom, etc). Lastly, women tend to work in areas close to their homesteads, while men travel longer distances to further from homesteads as they herd livestock. From the survey, about 75% of female adults rely on the agriculture extension officers' advice on what, when and how to plant compared, to 22% of elderly females (Table 11) with little effort to assess the risks themselves. Generally, 79% of adults are more [1]flexible to take advice from agriculture officers because they are given seeds through the poverty eradication programs (Table 11). Also, the adults indicate that they rely more on extension officers' advice because of the limited knowledge and experience in farming over different seasonal scenarios. Unlike the elderly who are likely to have more experience in observing changes in the seasons and managing agro-pastoralism. Extension officers rely on the meteorology report, with no reliance on traditional weather forecasting. Data from SSI reveal that, only 50% of elders

[1] Usage of traditional season and weather forecasting to make farming decisions is based on the respondent's perception.

are more willing to adopt the advice from the extension officers despite acquiring seeds from the poverty eradication program (Table 11).

4.6 Changes in the reliability of traditional weather forecasting indicators observed by agro-pastoralists in Bobirwa sub-district

Semi-structured interviews with traditional weather forecasters identified critical changes to weather and seasonal patterns experienced during their cropping seasons in Bobirwa sub-district. These changes have been highlighted by the traditional weather forecasters to not yield the same results they would generally expect, therefore may cause mistrust in the traditional weather projections and ultimately threaten their livelihoods. While some agro-pastoralists were able to recall the quality of years back related to incidents in their lives, most forecasters only remembered the past year to two years. To begin with, late rainfall was identified by 76% of intervieews as one of the notable changes in the sub-district. About 55% of interviewed forecasters indicate that rainfall is generally late reduced (Figure 2). In responding to the question on changes observed, one forecaster said; "Pula e boutsana," meaning there is little rainfall. Another change that has been noted by the pastoralists was the patchy trends that the rainfall occurs. The studies by (Kenabatho et al., 2012) support findings of reduced rainfall in Botswana, therefore impedes on the success of agro-pastoralism. The respondents highlight that these rains are puzzling new phenomena and are regarded as negative. One elder traditional weather forecaster said "Dipula tse di kgona go re tsietsa re solofetse gore pula e tla santse e tswelela." Results of this study are confirmed by other studies (Soropa et al., 2015), which indicate similar patchy rainfall in Zimbabwe. These patchy rains are indicated to occur in two ways heavy and soft. The intensity of the heavy rains has been observed to be more frequent with fewer soft rains, which is unlike the rainfall patterns they know. However, the heavy rains are undesired as the water runs off and do not seep into the soil to improve the moisture contents that the agro-pastoralists require for their crops and livestock. Studies by Simelton et al. (2013) show similarities to the findings of this study.

Other notable changes identified by the traditional weather forecasters include population increase (both livestock and human population) and commercialisation of agro-pastoralism. In all sites, participants reported that growth in human populations has encouraged intense land clearing to meet the increasing demand for crop production and increased livestock population for consumption and sale. The traditional weather forecasters emphasize the extent that this commercialisation disconnects each individual from their natural environment. They highlight that the lack of respect for the environment retaining depth of the traditional weather forecasting. This population growth has led to land fragmentation and overexploitation of the areas used for agro-pastoralism, depletion of soil fertility and increased soil erosion, reduced pasture areas and overall food production. All these land transformations are coupled with droughts exacerbate the impacts of the drought. Only 30% of participating forecasters indicate that the droughts are more intensive than they previously have experienced. The traditional weather forecasters in the Bobirwa sub-district indicate that the drought cycle in their region occurs every four to five years after a good season, with rainfall expected half-way through this cycle hence argue that the droughts get to be bad after five years. These forecasters however, indicate having lived through extreme droughts, they relate having intensive droughts. Although 8% if the elders expressed that the occurrence of cyclical reduced rainfall is not a new phenomenon, they express that the current reduction is extreme and not the same as before. The further express that the reduced rainfall creates difficult conditions to sustain their livelihoods.

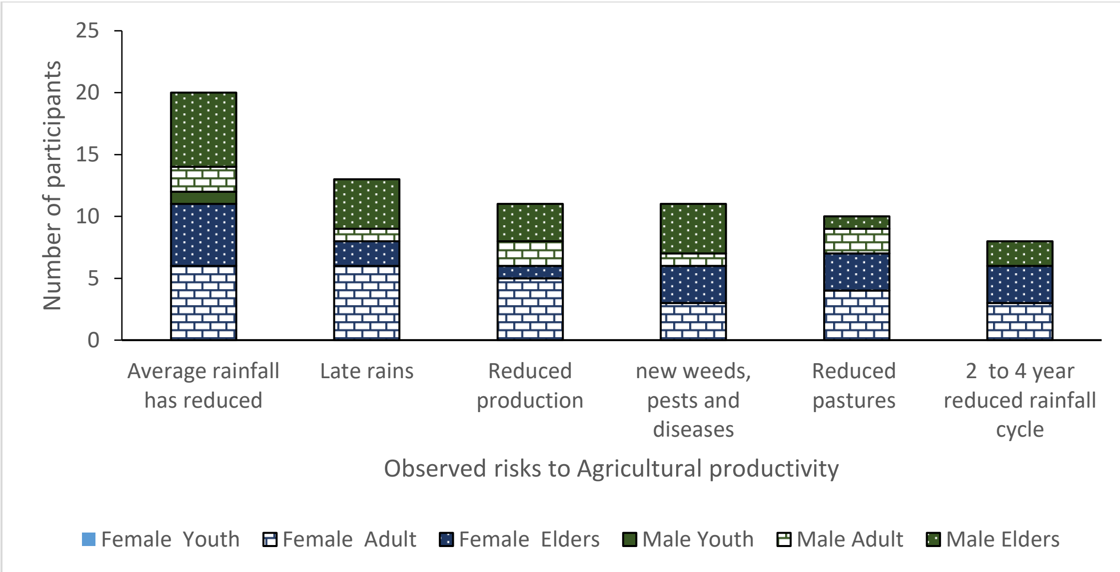
Among agro-pastoralists of the Bobirwa sub-district seasonal trends (28%) have been identified to question the accuracy of traditional weather forecasting. For example, it was noted that "when the frog crooks, it used to take about 2-3 days there is rain, however, these days it takes longer for the onset of the rains." Forecasters in the study indicate that weather patterns which have changed during the time that they engaged in traditional weather forecasting. However, the changes in the known weather patterns can disrupt the community or individuals' response to the newer weather patterns. These changes have probed the agro-pastoralists' activities to change to suit the weather patterns and retain less losses in their livelihoods.

The forecasters noted that the winds blowing from east to west, known to induce rainfall have changed. Currently, winds blowing from new directions or previously known directions which were characterised to not bring rainfall, are now observed to induce rainfall. In the context of these agro-pastoralists, these changes are attributed to God, ancestral beings and satellites used in weather forecasting. One respondent remarked that "wind direction has become confusing and therefore it is not used frequently unless the winds are coupled with clouds." For forecasters with limited knowledge of different indicators used in forecasting may Amongst other observed changes, cloud thickness, colour and direction of travel have been reported by forecasters to indicate different results than expected; therefore, could lead to bad decisions in their agro-pastoral planning. Respondents noted that the current extreme weather events that they experience tend to lead to high crop and livestock losses when there is a change in indicators, for example, the recent 2015 winds which caused damage to infrastructures, and the fog that was lethal to their crops in early 2016. Scenarios that traditional weather forecasting is based on are changing as established in the Bobirwa sub-district and in other areas. As such, the processes linked to different scenarios may lead to failure of coping mechanisms, if the agro-pastoralists do not alter their responses to indicator behaviour.

Traditional forecasters of the Bobirwa sub-district indicate that there are changes in the plant phenotypic responses which coincide with the recorded low humidity in the atmosphere and increased temperature attributed to climate change impacts. A study by Cleland et al. (2007) emphasised that there are shifting phenology indicators, which correspond to climate change. In terms of changes in the rainfall patterns that the agro-pastoralists are reliant, their adaptation techniques may be negatively influenced. The forecasters indicate that the plant signals can be misleading especially among adult forecasters and non-forecasters attempting to forecast, who often fail to follow the indicators properly. For instance, the high volumes of flowering by other plants that forecasters indicated they had not used previously for weather forecasting are trends that are coming up. Literature reflects that climate change has been linked to numerous plant phenology alterations (Ibáñez et al., 2010; Gillam, 2016). This results in individuals mistiming specific processes such as planting which could increase vulnerability to drought and seasonal flash flooding. According to the participants, the drought occurs in two stages, namely the drought for crops, which influences the cropping activities and the livestock; drought, which results in the depletion of pastures. Traditional weather forecasters indicate that they have observed crucial plant species such as the Morula, Mhata and moretologa used for forecasting are declining in the wild, often seen dying out (Kayombo et al., 2005). A study by McDowell et al. (2008) confirms results generated from this study, by confirming that recurring drought and warming have proven to exacerbate regional mortality of plant species that may be crucial in traditional weather forecasting. This could impede the process of traditional forecasting and the planning for upcoming season

To a lesser extent the semi-interviews indicate female adults have not paid attention to this particular cycle of drought, although they acknowledge the occurrence of droughts. Despite adult females not being observant, elderly females tend to be the most observant of the drought seasons Figure 2). Other issues that arose amongst the traditional weather forecasters include increased pest and diseases and the emergence of newer pests and weeds. These include increased occurrences of foot and mouth disease, which was previously not prevalent in the Bobirwa sub-district, American bollworms and weeds that the agro-pastoralists are not familiar with. Yet again, female adults tend to be least observant of emerging weeds and pests than other age groups. Weeds, pests and diseases often reduce the success of farming especially because the farming system does not evolve fast enough to allow agro-pastoralists to keep up with new challenges. These identified elevated risks on agricultural productivity increase the need for agro-pastoralists to be able to mitigate, prepare or overcome the risk and impacts. It is with no doubt that agro-pastoralists with limited observations of risks are more prone to maladapting.

Figure 2: Observed risks to agricultural productivity identified by different age groups and gender amongst agro-pastoralists in Bobirwa sub-district.



4.7 Use of traditional weather forecasting in decision making among crop farmers

The agro-pastoralists in the Bobirwa sub-district, as in other areas in Botswana, are mostly agro-pastoralists who practise agronomy and rear small stock (goats and sheep) and cattle. During the interviews forecasters and non-forecasters of traditional weather forecasting from different social groups were asked how they inform their decision in farming and general livelihoods. Non-forecasting agro-pastoralists who use traditional weather forecasting are able to access the traditional weather information through consultations with elders for planning and preparing for crop production activities (

Figure 3). The non-forecasters indicated their reliance on the forecasters to predetermine seasonal temperatures and rainfall and advice on planning for the season. The results reveal a clear indication that interest in traditional weather forecasting by participating agro-pastoralists is linked to its application in planning rain-fed agro-pastoralism to ensure the households are food secure. It has been identified that 60% of adult forecasters actively start assessing the environment for indicators to forecast for the upcoming season just before the beginning of the cropping season, mainly in September. However, some of the indicators have been observed from July by elder forecasters, as indicated in Tables 1-3. As the season progresses, the forecasters indicated that they require some of the indicators such as the travel of *Kopa dilalelo, lehututu*, *pela*, rainbow, etc., to derive additional weather information. Once the forecasters observe the indicators and generate their traditional weather forecast, the participants said that they modify their decisions to decrease unwanted impacts and to maximise on the expected conditions. Some agro-pastoralists indicated that, despite the indicators showing threat articulated to weather, they tend to ignore the threat with hope that they can salvage something from their high-risk decisions. These agro-pastoralists reported that they took these risks to produce crops and livestock that are palatable to them and are a significant in their livelihoods, such as keeping large numbers of livestock despite less grazing land available. The interviews showed that weather information is crucial to enable agro-pastoralists to cope with climate variability. However, it is also crucial that this traditional weather information is precise to enable the agro-pastoralists to make decisions on farming practices. Most crop farmers' actions tend to be associated more with maximising rainfall to increase soil moisture, planting crops that can withstand drought conditions, so preventing losses (

Figure 3). The farming activities that improve utilising soil moisture include planting after it rains, cultivating the soil to allow for water penetration from any rain that falls. For seed preparation, the agro-pastoralists engage in selecting early maturity seeds, and organising seeds based on the indicators. Lastly, agro-pastoralists mitigate the losses by reducing the area of cultivation or forfeit panting when the forecast indicates less rainfall (

Figure 3). Just as the agro-pastoralists in the Bobirwa sub-district, farmers in Sub-Saharan Africa also tend to reduce the area of cultivation during drought seasons (Cooper et al., 2008).

The agro-pastoralists in the study area also indicate that they plant the same crop at different times as the rainfall as a mechanism to reduce risks of losses. This is because the traditional weather forecasts do not stipulate the exact time that the rains are expected when considering the current patchy rainfall patterns. The overall number of female participants was generally higher than males and youth had little participation in farming activities. On the other hand, the majority of forecasters were elders. Adult females who are non-forecasters tend to make unprepared decisions based on their misunderstanding of general climate patterns and their influence on agro-pastoralism activities. From the study, it is depicted that the adults and youth tend to be new to farming, and so are not accustomed to practices that are associated with predicting weather and other related practices. From the interviews, about 50% of the agro-pastoralists still adopt older methods of food production that they learnt and acquired over the years including which crops to sow and when. These methods have been shaped by adopting farm activities to increase moisture content in the soil owing to the low rainfall received in the area. Less knowledge or 'know-how' of identifying hazard embodied in traditional weather forecasting in this regard is indicated to elevate risk in reduce impacts of flood.

Also, within the complex agro-pastoralism landscape, diversity of farm management and decision-making is influenced by other players, such as regulatory institutions. An example of these regulatory institutions includes the poverty eradication programmes that include other decision makers such as the extension officers, the tractor operators, and so on. The government of Botswana provides support to agro-pastoralists through poverty eradication programmes that provide seed and tractors for individual farmers. Within the poverty eradication programme, hybrid seeds that mature early are often prescribed and with incurred losses of crop varieties, 63% of female adults prefer using early maturity hybrid seeds compared to 100% of male adults, who use early maturing seeds (

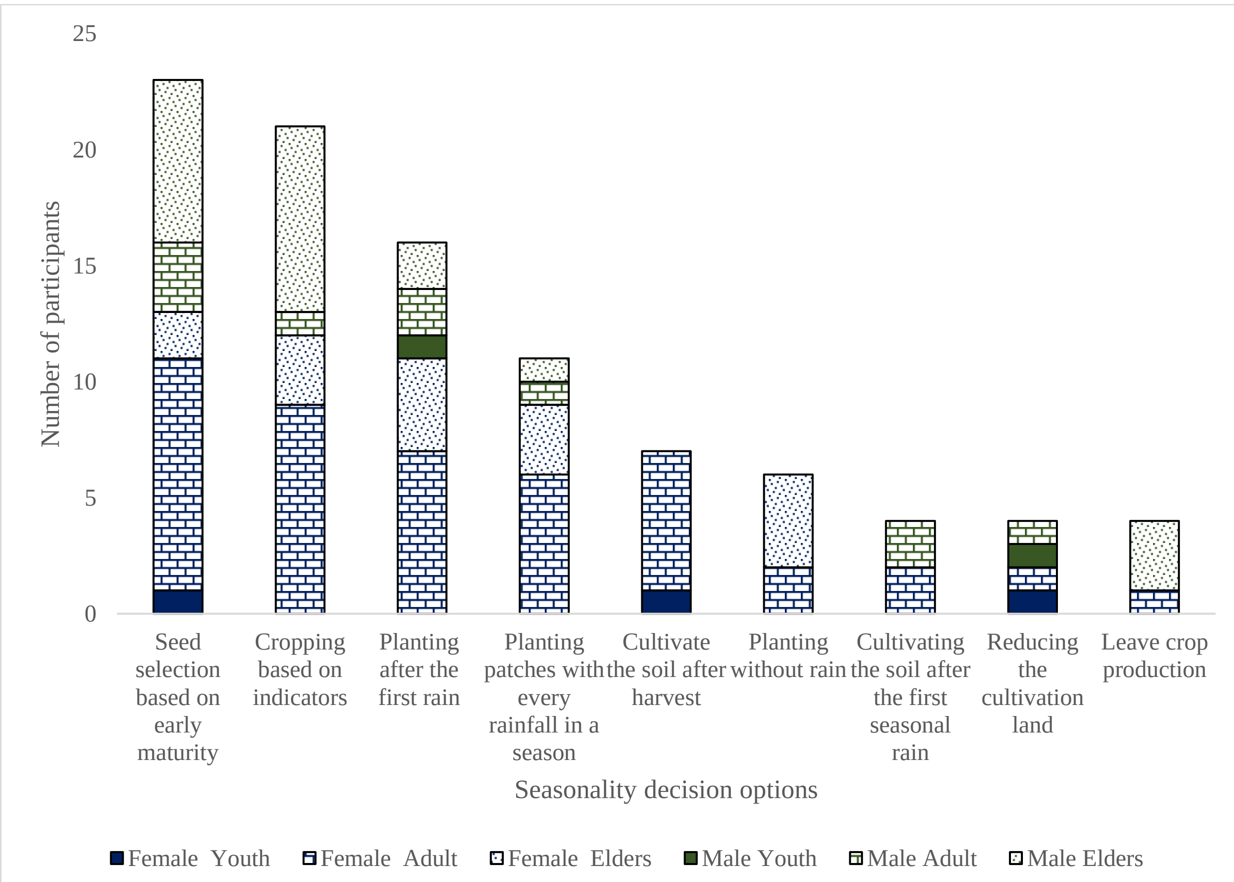
Figure 3). SSI indicate that 68% (13 of 19) adults select seeds based on early maturity, compared to 50% (9 of 18) elders and 50% (1 of 2) youth. 77% (10 of 13) males show to use early maturity varieties during predicted drought seasons using traditional weather indicators compared to 50% (13 of 26) females (

Figure 3). The elderly females indicate that they prefer the traditional seeds such as varieties like *Mokwetane* sorghum seeds which have a short life cycle but are not categorised as early maturity seed in accordance to the poverty alleviation programme and are less recognised by the Department of Agriculture. The study therefore depicts that females are more likely to select seeds that wouldn't yield during weather constrained seasons, unlike males who are less likely to choose seeds that aren't tolerant to weather constraints.

From SSI, results indicate that 37% (7 of 19) (Figure 3) adults sow seeds with every adequate rainfall compared to 22% (4 of 18) of elders (Figure 3) so as to use adequate moisture for seed germination. However, 35% (9 of 35) females actually use the adequate rainfall episodes to sow seeds compared to 15% (2 of 13) males (Figure 3)., agro-pastoralists indicate that despite the type of crop planted is also influenced by the traditional indicators used in weather forecasting, monitoring soil moisture during the season is also key to determine the sowing dates and influence pest avoidance. Seed-sowing of crops is done at different times for four basic reasons within the Bobirwa sub-district, namely: to utilise soil moisture, to avoid pests, to allow seedling development for seeds that take longer and can withstand drought conditions, depending on the rainfall episodes. This has been what prompts the elderly agro-pastoralists to sow seeds at different times depending on optimising the conditions at hand. Other agro-pastoralists however, show that they do not monitor rainfall episodes, but rather sow seeds before the rainfall season begins. From the results, to also increase penetration and retain soil moisture during predicted drought seasons, SSI indicate that 21% (4 of 19) adults say that they cultivate the soil after the first seasonal rainfall; with 8% (2 of 26) being females and 15% (2 of 13) being males. About 32% (6 of 19) adults cultivate soils after harvest despite the expected rainfall, whereas the elders do not indicate to cultivate the soils after harvest. Only females about 26% (7 of 26) have indicated to cultivate soils after harvesting. Cultivating the soil after harvest has been shown to reduce pests and improve water penetration (Abawi and Widmer, 2000; Holland, 2004), but this comes at a cost of losing carbon and nitrates in the soil (Johnston et al., 2009). In the context of the agro-pastoralists that do not cultivate after soils after harvesting, they may be prone to having poorer soils and reduced yields.

Due to ageing, the elderly agro-pastoralists' incapability to maintain the cropping land rather than weather changes is reduced, so they tend to reduce or quit cultivation. On the contrary, adults and youth tend to reduce or leave farming because of the inconsistent seasonal weather patterns that they fail to comprehend. Some agro-pastoralists indicate that they change harvesting date when rainfall is forecast to prevail during the time when crops are maturing. However, some agro-pastoralists indicate that they only harvest the crops at a particular stage and not prior to that stage. Despite the traditional weather forecasts that indicate upcoming rainfall, which could lead to damage to the harvest, the agro-pastoralists tend not to be keen to harvest early. One of the participants explained that 'sorghum, for example, cannot be harvested until it dries to a certain degree, and should it rain while the crops are developed, they do not harvest.' Rather, the sorghum could be left to germinate while on the stalk should it rain before the farmer is convinced that the grains are dry. Failure to change harvesting dates increases vulnerability of agro-pastoralists as their produce faces being lost.

Figure 3: Common activities in crop production by elderly males (EM; n=13), adult males (AM; n= 2), elderly females (EF; n=9) and adult females (AF; n=13) mentioned in semi-structured interviews (n=37) influenced by traditional weather forecasts.

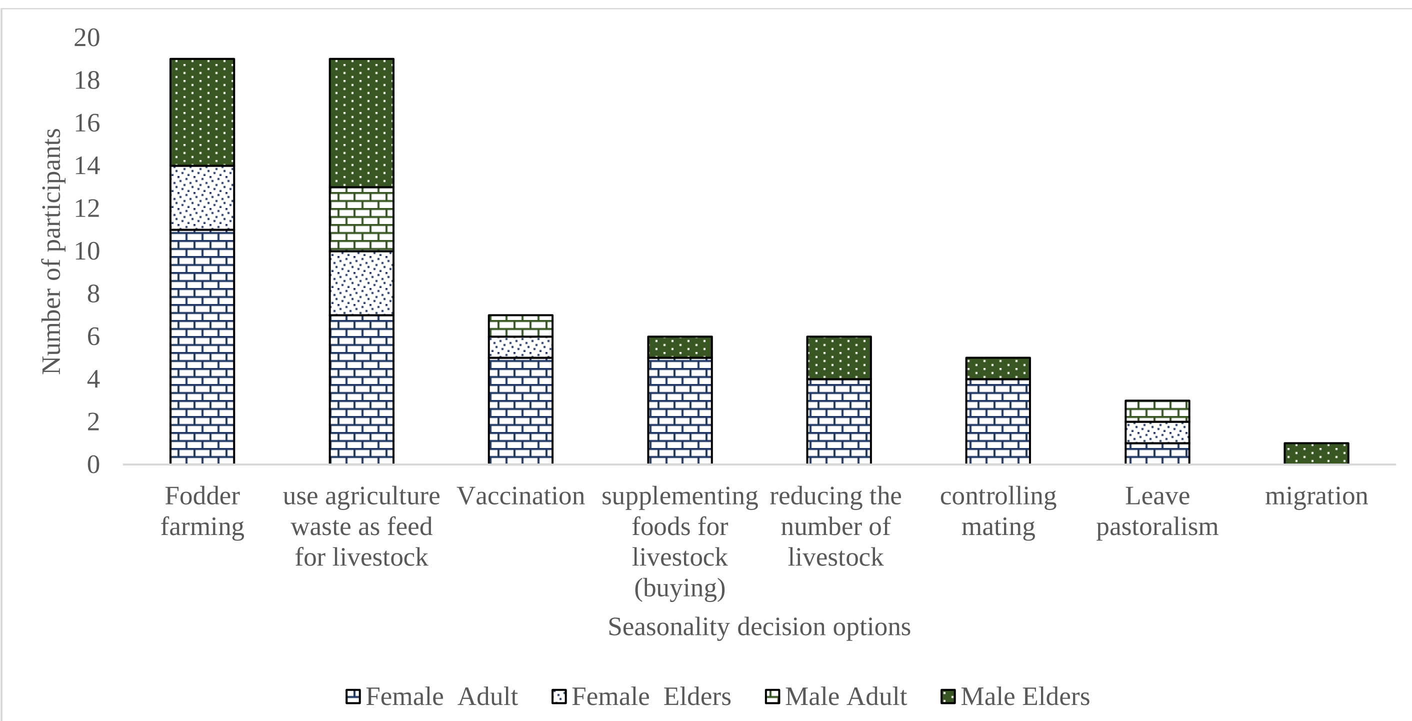


Climate variability influences economic and food security risks which these agro-pastoralists face. Accurate forecasts of climate are therefore required to allow the agro-pastoralists to take advantage of the favorable climate conditions and mitigate mismatches of agricultural production and climate. Findings of this study indicate that agro-pastoralists depend and rely on traditional weather forecasting when planning for their farming activities. Studies show that climate information is crucial in agricultural production, especially towards dealing with sustaining livelihoods and improve food security (Mase and Prokopy, 2014; Jost et al., 2016). The climate information acts as early warning systems to manage agricultural risks and allow agro-pastoralists to use the ethno-meteorology information to allocate agricultural resources accordingly. Utility of traditional weather and climate information is therefore crucial in building and enhancing social resilience in the study community vis-à-vis responding to household vulnerabilities and strengthening strategies to cope with food insecurity. Moeletsi et al (2013) suggest that agricultural productivity can be increased by using weather information in farming. In other countries, this is used as a mechanism of reducing impacts of agricultural production on the environment. For example, keeping livestock and crops enables the agro-pastoralist to have different food sources. Findings of this research are similar to those of countries such as Uganda (Okonya and Kroschel, 2013) and Zimbabwe (Shoko and Shoko, 2013). Studies indicate that breeding of agronomy crops has been used successfully to mitigate crop yield losses to climate change impact in eastern and Southern Africa (Jones and Thornton, 2009).

4.8 Use of traditional weather forecasting in decision making among pastoralists

Most agro-pastoralists in Bobirwa sub-district practise rain-fed pastoralism and base their decisions on information derived from traditional weather forecasting. The activities guiding decisions making was divided into disaster prevention by reducing the number of livestock, emergency fodder production as alternative feed for livestock, rearing or keeping multi-species composition of the herd as measures to mitigate the impacts of climate extremes. Agro-pastoralists indicate that different livestock consume pastures at different levels and that others are browsers, therefore, during drought when the diversity of livestock still leave them with animals that can utilise the pastures differently. Owing to climatic uncertainty, pastoralists adopt general conservation strategies to reduce losses for bad seasons. A greater percentage of agro-pastoralists in the Bobirwa sub-district use traditional weather forecasting to decide on supplementing the diet for their livestock (Figure 4). The results indicate that agro-pastoralists in Bobirwa are engaging in fodder farming 28 0f 37 (76%) and using waste from crop production as feed 27 of 37 (73%) and with 11 of 37 (30%) purchasing feed to supplement the livestock dietary requirements, especially with reduced pastures in their district (Figure 4). Seasonal migration is considered as a coping strategy by 4 of 37 (11%) of the total population of agro-pastoralist interviewed in Bobirwa sub-district. However, other pastoralists indicate that migration is a challenge owing to not having homes in other areas, hence they try and find opportunities where they are based. During drought periods, the agro-pastoralists in the Bobirwa sub-district tend to cull their livestock, with 4 of 37 (11%) of the respondents willing to quit or leave livestock rearing and only 9 of 37 (24%) reducing their herds 9 of 37 (24%) (Figure 4). Instead of reducing the herd, other agro-pastoralists opt to drive the herd longer distances in search of pastures, while more vulnerable and weaker stock remain around the kraal, where they are fed (Figure 4). The results reveal that more women reduce their livestock or quit pastoralism compared to male agro-pastoralists. The results also indicate that agro-pastoralists use weather forecasting to make decisions on controlling livestock mating and vaccination. For general management of livestock, vaccination 10 of 37 (27%) and controlled mating 7 of 37(19%) are informed by weather forecasting (Figure 4). Some of the elderly agro-pastoralist indicate that cattle do not mate during drought, but, once there is rainfall, the animals commence mating hence they are not actively attempting to control mating by separating the animals during drought. Studies by (Pellegrino et al., 2013) confirm that insect and animal mating may be influenced by availability of water, therefore during drought season, animals may not be observed to mate. Despite this, goat farmers indicate that goats tend to mate even in dry seasons and often lead to malnourished stock that tends to not get fit even during the rainy season. The pastoralists therefore point out the need to curb goats from mating, they often separate the males during drought. Because the pastoralists use free range farming methods, this is challenging as the goats are susceptible to mating by other males while grazing, hence other pastoralists do not see the need to separate the livestock. To a greater extent, female agro-pastoralists supplement the livestock using fodder and purchasing feedstock than male agro-pastoralists. Other agro-pastoralists indicate that they cannot change the situation much should the pasture be depleted.

Figure 4: Coping Strategies in pastoralism by elderly males (EM; n=13), adult males (AM; n= 2), elderly females (EF; n=9) and adult females (AF; n=13) and mentioned in semi-structured interviews (n=37) in Bobirwa sub-district to reduce impacts of climate variability.



The traditional weather forecasting is associated with biodiversity preservation. The cultural rituals that are practised by the societies in the Bobirwa sub-district associate with rainfall. These rituals include conservation of animals and plant species and the spaces they live in and are considered essential by the agro-pastoralists. Culturally, individuals used to strive to ensure that the ecosystems were preserved; however; this has been indicated to have changed. Also, fuelled by increased destitution, agro-pastoralists are presented with limited ability to support dangers that are currently threatening their livelihoods. These changes in the traditional weather forecasting, however, present increased risks in food production for the future in both adult and youth agro-pastoralists.

4.9 Threats to the reliability of traditional weather forecasting in Bobirwa sub-district

From the surveys, 15 of 18 (83%) of elderly ago-pastoralists indicate that some youth in their families would rather watch television than look at the stars and learn about the stars from the elderly. SSI show about 8 of 17 (47%) of adults (both male and females), 4 of 18 (22%) elders and all participating (100%) youth admit to watching their favorite programmes on television during the time that some indicators may be visible outside Table 11. This depicts that youth and adults are more likely to lack knowledge in traditional weather forecasting considering that intergenerational transfer of the knowledge on indicators was used as a form of entertainment, which is not a common practice nowadays results indicate that 7 of 13 (54%) of the participating female adults attest to watching television and missing watching the environmental cues, compared to 1 of 4 (25%) of their male counterparts Table 11. These findings conform to why more non-forecasters are females as depicted in this study (Table 5). The modern lifestyle also including technologies such as having electricity and televisions are believed to have replaced the traditional setup of telling tales and actually observing changes in the environment, which was previously used as a mode of transferring the knowledge from one generation to another. Interviewees mentioned they have not had a chance to practise and refine the skills of traditional weather forecasting 20 of 37 (54%) and indicated their knowledge is limited because of living in the cities 7 of 37 (19%) (Table 11). Previously, traditional forecasters indicate that they acquired the knowledge through oral means while farming with elders, such as when herding cattle to the kraals from water points; often this was the time that stars like *Kopa dilalelo* were spotted. Also, during dinner (*dilalelo*), the elders would narrate the skills of forecasting. As elaborated in literature, knowledge of the weather forecasting indicators is often associated with social responsibilities and how individuals spend their time Gómez-Baggethun and Reyes-García, (2013). Given that agro-pastoralists now engage in activities such as watching television and leaving in peri-urban areas, where there is limited interaction with the traditional weather indicators, hence this poses a threat to individuals knowing and using these indicators.

About 13 of 37 (35%) of forecasters in the Bobirwa sub-district highlight that new seasonal patterns may fuel failure to understand and find unreliable (Table 11). Changes in seasonal trends 7 of 37 (19%) have been identified to question the accuracy of traditional weather forecasting. Only 5 of 37 (14%) of the participating forecasters responded that the indicators are not the same. Examples of indicators that have changed include the direction of travel of clouds which have previously been known to not bring rainfall, are currently bringing rainfall. Agro-pastoralists indicate that the sign can throw their predictions off when they use their accumulated knowledge. Increase in temperatures and decline in rainfall will have negative impacts on the ecology – for example, the species that are used in traditional weather forecasting may appear when the forecasters are not actively watching out for the indicators as they show that they actively forecast mostly from September. Literature has also indicated that changes in seasonal trends may lead to individual traditional weather forecasters questioning the accuracy of the forecasts (Mapfumo et al., 2015; Armatas et al., 2016; Jiri et al., 2016). The agro-pastoralists recognise that there are newer species, both plants and animals, that occur in their area and others disappearing, including trees and birds. The disappearing of the species is fuelled by land changes into ploughing fields and overpopulation of livestock and over-harvesting in the wild. However, these could potentially cause the populations of indicators used for traditional weather forecasting to dwindle.

Interviewees also mentioned that there has also been a breakdown in the tradition of working together in the community and exchanging knowledge 16 of 37 (43%), in terms of societies moving from basic society with responsibility to a more 'rights-orientated society'. The communities' rights-based discourse has clouded the understanding and application of traditional weather forecasting. As indicated above, most adults and youth have limited knowledge about the indicators and their behaviour used in traditional weather forecasting. SSI depict 16 of 37 (43%) of traditional forecasters to indicate that youth are resistant to learn traditional weather forecasting and often do not want to engage in agro-pastoralism but would rather get formal jobs. Also, the youth deemed the use of traditional/ cultural activities as barbaric and therefore engage with it to a lesser extent. SSI with non-forecasters indicate that some agro-pastoralists view traditional weather forecasting as barbaric, owing to influences of Eurocentric perceptions that tend to discredit traditional beliefs. Studies by Leonard et al. (2013); Garutsa and Nekhwevha (2016) with similar results also show that Western hegemonic practices impede the proper utilization of traditional practices. This was indicated in the interviews with both non-forecasters and forecasters who highlight non-forecasters in their families. Moreover, 4 of 18 (22%) of elder agro-pastoralists from the study sites indicate that migration to cities threatens the existence of traditional weather and seasonal forecasting, while only 1 of 17 (6%) of the adults agree with this (Table 11). The adults and youth highlight that within their communities, it is difficult to make a living out of farming, and hence they decide to look for opportunities elsewhere, often in urban and peri-urban areas. The opportunities sought out by adults and youth create and influx of rural to urban migration, with less attention given to agro-pastoralism. This and the lack of interest in agricultural activities are believed to have led to disengagement of youth to engage in agro-pastoralism, hence condemning the traditional weather forecasting. Also, exacerbating existing stresses on traditional weather and seasonal forecasting, the poverty reduction programmes by the government, which agro-pastoralists tend to rely on and give less effort in committing to agro-pastoralism. One of the interviewees said that most people enroll for the government programmes and therefore fail to commit to agro-pastoralism. To a greater extent 8 of 18 (44%) of elders highlight these government programmes, compared to 4 of 17 (24%) of adults; however, the views of both males and females are the same (Table 11). 20 of 37 (57%) forecasters indicate that migration to peri-urban areas is one of the reasons there is limitations in using traditional weather forecasting.

Agro-pastoralists in the Bobirwa sub-district indicate that transgenerational transfer and usage of traditional weather forecasting by adults and youth is prevented by the Christian religion, education system and urban migration. When conducting semi-structured interviews, it was noted that numerous non-forecasters indicated dissociation with traditional weather forecasting. This was noted when posing the questions on traditional weather forecasting, and participants showed negative reception and would generally say “We are Christians, we do not associate with the use of traditional beliefs; hence, we don’t rely on traditional weather forecasting”. This further indicates hindrance of non-forecasters using traditional weather forecasting due to their Christian belief. When the non-forecasters were questioned on how the agro-pastoralists identify weather-related risks, these non-forecasters indicated to not assess risk. They rather sow their seeds just as winter ends and hope that God will bless them with enough rainfall to avail food for them. However, this increases vulnerability to maladaptation in terms of choice of crops. These results show that failure of the agro-pastoralists to observe and use the indicators threatens the existence of the traditional weather forecasting. The non-forecasters have also been noted to condemn and highlight the unreliability of the traditional weather forecasting while they do not have the knowledge. On the other hand, believers are reliant on the traditional forecasting knowledge and some wish they could learn of more indicators (Table 11). The non-holders believe the traditional weather forecasts given by their elders (especially the female elders) is often reliable, hence their belief in the traditional weather forecasting.

Table 11: Threats to Traditional weather forecasting identified by elderly males (EM; n=12), adult males (AM; n= 4), elderly females (EF; n=6) and adult females (AF; n=13) and mentioned in semi-structured interviews (n=35) in Bobirwa sub-district

Threat	**Quotation**	**Total number of interview respondents (n=35)**	
Failure to use indicators	Traditional weather forecasting is practiced by people who are active in agro-pastoralism. Adults and youth indicate their limited engagement in forecasting as they are new to farming. Re le banana, ga re ise re nne le tshono ya go ithuta go leba loapi re tlhatlhoba seemo sa pula, re basha mo temo thuong, re santse re ise re nne le kitso epe e ntsi.	E;M (12)	8 (67%)
		A;M (4)	2 (50%)
		E;F (6)	4 (67%)
		A;F (13)	9 (69%)
		Total	**23**
Relations in the community	The basis of the traditional weather forecasting is built around respect for the ecosystems and for the traditional structure. Kgwetlho e re nang le yon eke go tlhoka tlhompho mo tikologong ya rona	E;M (12)	6 (50%)
		A;M (4)	3 (75%)
		E;F (6)	4 (67%)
		A;F (13)	3 (23%)
		Total	**16**

Resistance of youth to learn	Traditional weather forecasting is 'the thing of the past', we don't believe in it and therefore it doesn't work for us. Rona re banana, gare dirisise dilo tsa bogologolo tse di sa berekeng.	E;M (12)	8 (67%)
		A;M (4)	2 (50%)
		E;F (6)	3 (50%)
		A;F (13)	3 (23%)
		Total	**16**
Television	The current lifestyle has our lives revolves around watching soapies and TV programmes. At these times, the indicators may be visible outside and we forego noticing them. Matshelo a rona a malatsi a, re nna re itepatepantse le TV. Dinako tse e leng gore dinaledi di kaa loapi ko ntle, retla bo re lebile ditori mo TV.	E;M (12)	3 (25%)
		A;M (4)	1 (25%)
		E;F (6)	1 (17%)
		A;F (13)	7 (54%)
		Total	**12**
Church	"One cannot go to church and believe in traditional practices. These practices are demonic and are not recognised by our church." "Kereke ya rona gae letlelele ditumelo tsa setso ka di sa tsamaisane gotlhelele le tumelo ya sekereki. Ka jalo ga gona gope fa re amanang teng le setso."	E;M (12)	8 (67%)
		A;M (4)	3 (75%)
		E;F (6)	6 (100%)
		A;F (13)	4 (31%)
		Total	**21**
Poverty eradication programs	The poverty eradication programs bring about selfishness within the individuals of the community. People tend to want to dip their fingers in all pot of the poverty eradication programs and therefore no lack of dedication to any program. This ends up leading to wasting stare funds. Mananeo a ga goromente a rotloetsa boitseme mo bathing ka ba batla go ikwadisa mo mananeong otlhe, e bo ba sa tsenye nama mo go one.	E;M (12)	4 (33%)
		A;M (4)	1 (25%)
		E;F (6)	4 (67%)
		A;F (13)	3 (23%)
		Total	**12**
Changes in seasonal trends	There are changes in the climate and seasons and this can be confusing especially that we already have pre-set mindsets on what to expect. Loapi le a fetoga, dipaka tsa maloba ga di sa tlhole di tshwana le tsa gompieno. Ga re tlhole re itse gore nako ya pula ke efe, e e seng ya pula ke efe.	E;M (12)	3 (23%)
		A;M (4)	0 (0%)
		E;F (6)	2 (23%)
		A;F (13)	2 (15%)
		Total	**7**
Living in cities	We often move to the peri-urban areas for work and because our lifestyles now are changing." Gantsi re nna mo toropong ka gore re tlwaela go nna teng.	E;M (12)	6 (50%)
		A;M (4)	2 (50%)
		E;F (6)	6 (100%)

		A;F (13)	6 (46%)
		Total	**20**

It is anticipated that the climate variability and change in the Bobirwa sub-district will have a negative impact on the coping capacity of agro-pastoralists. During interviews, questions were posed to determine threats that forecasters and non-forecasters of traditional weather forecasting have observed. For traditional weather forecasting to thrive, practical application of environmental changes is required to better inform decisions on everyday life activities with the changes so that there is constant food production. Globalisation and modernity, including Western education, television and lifestyle, are noted to be different from the old traditional ways, thereby influencing the intergenerational exchange of traditional weather forecasting. Most agro-pastoralists who have adopted the Western lifestyle do not put effort into learning traditional and cultural ways as there is television and internet at their disposal to get information. There have been considerable gradual changes in the rural livelihoods post-colonial times with regards to farming and schooling (Bryceson, 2002; Agrawal, 2014). The Bobirwa society has also been experiencing these transformations which filter through to social and the economic systems (Kolawole et al., 2014b). This modern living as identified by the agro-pastoralists has led to being self-sufficient and increasing market based agricultural activities such as farming to sell produce. However, owing to most individuals being smallholder farmers, they tend to sell off their produce and still require purchasing food items. This increases their vulnerabilities to food insecurities. In an interview with an elderly woman, she stated “We are often encouraged to sell our produce to make money, yet we end up having to go and buy the groceries back at a high cost. This leaves us more vulnerable to food insecurity.” The land system in the country is divided into three categories, namely village, lands and cattle-post, so the absorption of traditional weather forecasting is not seen to be prevalent in villages where most of the farmers reside and commute to the lands and cattle-posts. Most agro-pastoralists live in villages or towns, where most of the modernised way of life persists. Some interviewees expressed interest in learning to conduct traditional weather forecasting but said that they had not had the chance to learn because they had not spent time at the lands with agro-pastoralists as the fields are far from the village where the children attend schools. Some youth would rather watch television than look at the stars and learn about the stars from the elderly.

The poverty eradication policies that are established to assist the agro-pastoralists can be an inhibiting factor in the traditional weather forecasting. In this case, the government provides seeds for farmers as an assisting mechanism; the agriculture extension officers then give advice on the selection of crops, based on the scientific meteorological report. The results of this study are similar to those from Kenya, where policies on agro-pastoralism are influenced by scientific forecasting with skepticism on traditional forecasting (ole Saitabau, 2014). Studies by Kolawole et al., (2014a) highlight the disinterest of youth in agro-pastoralism, which corresponds to the findings of the current study. Studies in Tanzania also show that agro-pastoralists tend not to actively forecast and wait to receive assistance from the government programmes (Elia et al., 2014).

4.10 Summary

Each coping strategy is underpinned by a set of traditional values that define what is considered to merit the effort of agro-pastoralism and serves to provide standards that guide individuals' decisions, choices. Adopting a gendered and age perspective in traditional weather forecasting and social resilience studies acknowledges the imbalances and marginalisation of knowledge that makes particular groups vulnerable to maladapting to droughts and floods and possibly being unsustainable. It has been identified that there are numerous threats to traditional weather forecasting which impede coping with climate variability. It is evident that traditional weather forecasting is crucial in planning and making decisions for the forthcoming season in order for agro-pastoralists to attain sustainable livelihoods and be food-secure. Given the increasing risk of yield reduction in agro-pastoralism due to global warming and it is becoming more important for individuals to be able to tailor-make their production according to the weather or climate. Additionally, traditional weather forecasting closely monitors plant, bird, amphibians and insect species in terms of their physiological attributes and migration patterns.

Chapter 5

5.1. Conclusion

Weather is an important part of agro-pastoralism in the Bobirwa sub-district, but its role in enhancing livelihoods is dependent on the ability to forecast and plan for the predicted weather events. This is because agro-pastoralists' livelihoods are dependent on optimum weather conditions. Based on the evidence in the previous section, we can respond to the question on the resilience of different age and gender groups of agro-pastoralists in our sample. It can be concluded that the age and gender of agro-pastoralists in the Bobirwa sub-district are contributing factors to the use of traditional weather forecasting. The traditional forecasters in Bobirwa sub-district rely on biotic and abiotic indicators to generate weather information and they base decision making for their agricultural activities on this traditional weather generated information. The study demonstrates the richness of traditional weather forecasting in key planning and decision making for agro-pastoral activities and in coping with the current intense and prolonged droughts and flash-flooding experienced in the area. Despite the increasing climate risks observed by the agro-pastoralists, generating traditional weather information and coming up with coping strategies is dependent on knowledge, attitude and perceptions of an individual. As indicated in the results, it is evident that planning and coping strategies to drought are positively influenced by the knowledge of traditional weather forecasting of individual agro-pastoralists, whereas agro-pastoralists with limited knowledge of indicators have fewer coping strategies. This knowledge about traditional weather indicators, planning and coping strategies is further shown to be different among youth, adults and the elderly. The study established that traditional weather forecasting in the study area is highly influenced by attitudes and perception of agro-pastoralists and determines its rate of adoption during droughts and floods. Agro-pastoralists who are sceptical of traditional weather forecasting tend to discredit its accuracy. This group of agro-pastoralists are found to be more vulnerable to climate variability as they do not plan according to any form of weather information projections nor do they alter their agro-pastoralism activities to suit the expected rainfall. This however, increases chances of maladaptation, leaving the non-believers of traditional weather forecasting vulnrerable to climate variability. The evidence presented indicate that relevance and reliability is largely a matter of agro-pastoralists' perception of the traditional weather forecasting, which according to the study is influenced by different age and gender groups.

Predictions of rainfall onset or seasonal outlook assist agro-pastoralists to decide on type of crops to sow, cropping patterns that would be employed in the season and to plan different farming activities. Proper scheduling of these activities is important to maximise the use of moisture that the rains provide considering that the limited and patchy rains experienced in the area. Producing and increasing productivity of the agricultural output are crucial for agro-pastoralists to sustain their livelihoods and food security. Traditional weather forecasting using biological, atmospheric and astronomical cues are commonly used as indicators predictions on the occurrence of drought and floods and serve as traditional early warning system. However, the use of this traditional early warning system is differentiated according to age and gender. Using indicators easily accessible in homesteads, such as constellations, are more common among females than males, whereas indicators noticed away from the homestead such as plant phenology are common among males. In terms of age, more adults and youth spend more time in villages where they do not get to see any indicators and often discredit the credibility of this traditional weather forecasting, therefore their use of indicators to forecast are limited. Agro-pastoralist who forecast indicates that they have identified changes in the seasonal changes which may negatively influence their coping strategies to climate variations such as drought. Since the agro-pastoralists use the conventional calendars and have linked the timing of rainfall with the months, decisions to plant, cull livestock or forfeit planting can be misleading as the seasons are changing. These agro-pastoralists have high risks of maladaptation rather than the indicators failing as it is highlighted that especially the adults tend not to consider whether the predictions are true.

The marginalisation of traditional weather forecasting skills, practices and knowledge in agro-pastoralism emanate from modernisation fuelled by urban migration, formal education, lifestyle choices and Christianity. Findings indicate that traditional weather forecasting plays a critical role in monitoring biodiversity, sustainable agriculture and food security, which are crucial in achieving Botswana's SDGs implementation. If properly utilised in improving the success of agro-pastoralism they may ensure sustainable rural livelihoods.

Indeed, the adults and youth who are starting to engage in agro-pastoralism indicate that they are enthusiastic to learn how to better manage their crops and livestock. In encouraging the use of traditional weather forecasting, it would allow them to continue with macro weather forecasts. This presents an opportunity to bridge the gap between ancient wisdom and modern sciences, in the context of a threat to loss of cultural knowledge. Also, there is limited documentation of this knowledge available to the agro-pastoralists who are not constantly in the rural areas; therefore, it is not easily transferable to adults and youth who reside in villages where they do not have time to interact with the elderly to acquire the knowledge. It is therefore imperative for different institutions to work with agro-pastoralists to strengthen their ability to identify risks and improve their decision making to improve their resilience, especially with adults and youth. It can be argued, however that traditional weather forecasting cannot be used in isolation without being complemented with scientific knowledge. It has been established that multi-sectoral and interdisciplinary collaboration among all concerned actors at each stage in the forecasting process from continued observations to response and evaluation is important. However, currently in Botswana, there is less linkage between the agro-pastoralism based knowledge base and the national meteorology department that is currently influencing decisions on activities by agro-pastoralists through poverty alleviation programs. Secondly, based on the fact that local indicators of weather and seasonal forecasting are based on experience acquired through continued observations, this presents varied coping strategies to different weather events, hence prompts more collaborative approaches to mitigate impacts of climate variability on agro-pastoralism.

5.2. Recommendations

Acknowledging previously marginalised traditional weather forecasting and drawing simplistic conclusions of whether science or traditional knowledge are more adequate for generating weather information should be avoided. When addressing sustainable rural livelihood problems, there is a need for inclusive and participatory approaches which accommodate age, gender and are sensitive to knowledge held by different social groups. A key finding from this study is that marginalising and excluding traditional weather forecasting held by elderly female and male agro-pastoralists has compromised planning for and decision-making in agricultural activities. Both traditional and scientific weather forecasting contributes to narrowing the scale to more localised data compared to depending solely on scientific methods. Future research should attempt to link traditional and scientific knowledge into a single operational framework to improve weather forecasts (Galacgac and Balisacan, 2009; Kolawole et al., 2014b; Singh et al., 2017). Such a framework could be instrumental in weather information for the Bobirwa sub-district which is one of the areas with weather information data deficiency in Botswana. Engaging the agro-pastoralists in the process of generating and disseminating weather forecasts, may offer better packaged climate information that considers the needs of agro-pastoralists.

Though it was beyond the scope of this study, it was established that 89% of the participating agro-pastoralists, including both non-forecasters and forecasters of traditional weather forecasting across all age groups, highlighted the need for training as they find that the traditional weather forecasting as integral to their success in agro-pastoralism. This resulted from realisation that the traditional weather forecasting also serves as low cost strategies to manage crop and livestock losses, cropping according to water requirements of crops, pests and diseases, hence improve food availability. Based on the agro-pastoralists' views, this study therefore proposes that the untapped potential of the traditional weather forecasting supported to improve accessibility to youth and adults engaging in agro-pastoralism.

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Appendix A: Informed Voluntary Consent to Participate in Research Study

Project Title: The use of traditional knowledge on weather forecasting by different social groups in the face of climate change in Bobirwa sub-district

Invitation to participate and benefits: You are invited to participate in a research study conducted with researchers at the Adaptation at Scale in Semi-Arid Regions (ASSAR). The study aim is to develop a better understanding of how traditional weather forecasting is generated and used among socially differentiated groups I believe that your experience would be a valuable source of information, and hope that by participating you may gain useful knowledge.

Procedures: During this study, you will be asked to engage in a discussion around a set of open questions which will require you to answer at your discursion.

Risks: There are no potential harmful risks your participation in this study.

Disclaimer/Withdrawal: Your participation is completely voluntary; you may refuse to participate, and you may withdraw at any time without having to state a reason and without any prejudice or penalty against you. Should you choose to withdraw, the researcher commits not to use any of the information you have provided without your signed consent. Note that the researcher may also withdraw you from the study at any time.

Confidentiality: All information collected in this study will be kept private in that you will not be identified by name or by affiliation to an institution. Confidentiality and anonymity will be maintained through the use of pseudonyms where necessary throughout the reporting.

What signing this form means:

By signing this consent form, you agree to participate in this research study. The aim, procedures to be used, as well as the potential risks and benefits of your participation have been explained verbally to you in detail, using this form. Refusal to participate in or withdrawal from this study at any time will have no effect on you in any way. You are free to contact me, to ask questions or request further information, at any time during this research.

I agree to participate in this research (tick one box)

☐ Yes ☐ No _________ (Initials)

______________________	______________________	________
Name of Participant	Signature of Participant	Date

______________________	______________________	________
Name of Researcher	Signature of Researcher	Date

Appendix B: Translated Setswana Consent form

Setlhogo: Tiriso ya Pego ya Tebelopele ya Paka ya Pula (Tepo Loapi), Bobirwa Sub-District,

Taleletso go tsaya karolo: Re go laletsa go ithaopa go tsaya karolo mo dipatisisong tsa tiriso ya pego ya Tepo ya Loapi.

1. Tebelopele ya paka ya pula go tswa ko Tepo Loapi
2. Go o lepa loapi ka Setso

Puisanyo: Re a go buisanya ka tiriso ya pego ya paka ya pula, boleng ja yone, a e maleba le fa o leng teng, tiriso ya go lepa go lepa loapi ka setso, le gore a e a ikanyega.

Dipuisanyo tse, ke tsa dipatisiso fela, maina a lona ga a na go tlhagelela mo mokwalong wa dipego. Jaanong re kopa gore le akgele ka kgololesego.

Go baya monwana go supa tumalano (saena):

Ke dumalana le go tsaya karolo mo dipuisanong tse.

______________________	______________________	__________
Leina la moithaopi	Monwana	Letsatsi
______________________	______________________	__________
Leina la mosekaseki	Monwana	Letsatsi

Appendix C: Semi-structured interview guide

Demographics

a) Gender
b) Age group
c) Type of agriculture (commercial/subsistence)
d) Agronomy/ Pastoralist/combines

Objective 1. Understanding traditional weather forecasting knowledge in Bobirwa sub-district vis-à-vis farming and livelihoods planning and decision-making

a. What local beliefs and practices help you in planning and making decisions with respect to your agricultural activities (i.e. both crop and livestock-related) and general livelihoods activities
b. How did each of these beliefs and practices come about?
   [Probing: in terms of whether they have been passed over generations; learnt through their own experiences; or learnt from other communities; players involved in the generation of these beliefs and practices etc.]
c. How do the predictions inform your livelihood?
   [Probe: Time to vaccinate, plough harvest mophane etc.]
d. How effective have these local beliefs and practices been in helping them to accurately (a) plan their cropping and livestock activities and (b) make decisions about their livelihoods both in long and in short term.
   [Probing in terms of comparisons with other sources information for example from scientific sources]
e. Do both the young and old believe in the utility of the named local beliefs and practices? If not, why?
   [Probe: Are there any differences in the beliefs and use of the mentioned local knowledge by the young and the old? If yes. Why?
f. What indicators do you use in predicting for rain? (will depend on whether rain predictions are one of the local beliefs and practices. If it is not, it will be replaced with the common practice).
   [Probe: Insects, birds, plant phenology; astronomical cues. Differentiated into believes and practices by different gender and age group].
g. What did you use in your last seasonal and weather prediction?
h. Some of you use different signs methods to predict weather and seasons. Do you have any differences in the process of predicting?
   [Probe: why do you think these differences exist?]
i. What myths, beliefs and practices are guarded for weather forecasting
   [Probe: in terms of whether the use of these beliefs and practices is more prevalent among the elderly/or whether the rest of the community members are also actively utilizing them.
j. Do you use follow up weather predictions once you have planted (or rather during the rainy season?
   [Probe: what kind of follow up? Are the follow ups accurate? Why so?]

Objective 2. Understanding how the use of traditional weather forecasting knowledge is differentiated by social groups

a. Do both the young and old believe in the utility of the named local beliefs and practices? If not, why?
b. What have been the patterns of use of these beliefs and practices over time when comparing the elderly and the rest of community members in as far as (i) seasonal cropping and livelihood activities and (ii) other livelihood activities are concerned (Probing in terms of whether the use of these beliefs and practices is more prevalent among the elderly/or whether the rest of the community members are also actively utilizing them)
c. Any differences in the use and/or belief in the utility of local beliefs and practices among male and female agro-pastoralists? If yes, what are these differences?
d. Do daily activities by men and women of different age groups influence the choice of probes used in predictions?

Objective 3. Explore changes in (and reasons behind) the reliability and use of traditional weather forecasting knowledge

a. Have there been changes in (i) the use of and (ii) reliance on local beliefs and practices over the years vis-à-vis planning and decision-making at the seasonal time-scale
   [Probe: has there been changes in the signs used; the frequency of use and level of importance of weather forecasting?
b. If yes, what have been the changes and what have been the reasons behind? If not, why?
c. [Probe: Do you feel like weather predictions for the last season were accurate? How about in previous years, as far as you can remember?
d. Do you think there is need for improving the generation and/or use and uptake of local beliefs and practices into the future? If yes, what are the improvements that you would suggest?
   [Probe: why or why not? What make you think this?]

   Probes
e. How has the predictions been changing over time?
   [Probe: what are the notable changes?]
f. What did you use in your last seasonal and weather prediction?

Appendix D: Key informants' interview guide

1. Spirit mediums
2. Individuals who are identified to be knowledgeable about predictions (ie selected village elders)
3. Agriculture extension officers
4. Meteorology department

Objective 1. Understanding traditional weather forecasting knowledge in Bobirwa sub-district vis-à-vis farming and livelihoods planning and decision-making

i. What farming practices are informed by traditional knowledge?
ii. Are there local believes and practices utilized in the area with respect to farming and general livelihoods?
    a. If yes, what are these?
iii. How do the predictions come about?
iv. What is being predicted for? (The beginning of the rain; amount; temperature; wind).
v. In your opinion, who participates in the process of weather predictions?
vi. How effective and accurate are the predictions in the preparatory process of the farming practices?

Objective 2. Understanding how the use of traditional knowledge in weather forecasting is differentiated by social groups

What indicators do you use in predicting for weather?

Indicator	**Signs used to related to weather**			
	Male		**Female**	
	Young	**Old**	**Young**	**Old**
Insects List of 5-8 identified insects				
Plant phenology List of 5-8 identified plants				
Birds List of 5-8 identified birds				
The moon and the sun List of 5-8 identified				

Objective 3. Explore changes in (and reasons behind) the reliability and use of traditional weather forecasting knowledge

Has there been changes in predictions or the indicators? And why?

Indicator	**1990-1995**			**1996-2000**			**2001-2005**			**2006-2010**			**2011-2015**		
	Precipitation			Precipitation			Precipitation			Precipitation			Precipitation		
	High	normal	Low	High	Normal	Low	High	Normal	Low	High	Normal	Low	High	Normal	Low
	Reasons			Reasons			Reasons			Reasons			Reasons		
Insects For example (were the particular insects identified in the focus groups dominant in the particular year and does it correlate with the precipitation in that year)	Indicator			Indicator			Indicator			Indicator			Indicator		
	High	Normal	Low	High	Normal	Low	High	Normal	low	High	Normal	low	High	Normal	Low
	Reasons			Reasons			Reasons			Reasons			Reasons		
Plant phenology For example (were the particular plant phenology identified in the focus groups dominant in the particular year and	High	Normal	Low	High	Normal	Low	High	Normal	Low	High	Normal	Low	High	Normal	Low
	Reason			Reason			Reason			Reason			Reason		

does it correlate with the precipitation in that year)															
Birds For example (were	High	Normal	Low	High	Normal	Lo w	High	Normal	Lo w	High	Normal		High	Normal	Low
the particular birds	Reasons			Reasons			Reasons			Reasons			Reasons		
identified in the focus groups dominant in the particular year and does it correlate with the precipitation in that year)															
The astronomical cues	High	Normal	Low	High	Normal	Lo w	High	Normal	Lo w	High	Normal	Low	High	Normal	Low
For example (were	Reasons			Reasons			Reasons			Reasons			Reasons		
the particular astronomical cues identified in the focus groups dominant in the particular year and does it correlate with the precipitation in that year)															

NB. The years will change as far back as the interviewee can recall. And the indicators will also change to what the agro-pastoralists use. The table is just there as a guide.