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Analysis of Use and Value of Weather and Climate Information for Commercial Arable Farmers in Botswana

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Abstract

Weather and climate forecasting information has been touted as having the potential to be valuable to users by aiding their decision making and preparedness to the risks associated with variable climates. Understanding the context within which forecasts can be and are used gives insight into whether the forecasts are meeting their potential usefulness and value. This thesis analysed the uptake and use of climate prediction information into the decision making of commercial farmers in Pandamatenga, Botswana to gauge the value of the information. The Pandamatenga farmers are the major producers of crop produce in Botswana and so are a key component to achieving food security but are subject to highly variable weather and climate conditions which can result in variable yield amounts. A survey was designed to gain an understanding of how the farmers access, perceive and use forecasts. Focus was given to weather forecasts, seasonal forecasts and climate change information. A framework focusing on four prerequisites needed for forecast use was developed to aid the analysis of the survey results. These prerequisites are: access to forecasts; quality of the forecast; confidence in the forecast; and the situation of the farmer allowing for the forecast to influence choice. It was found that the weather forecast was the most used and therefore valuable forecast as it met all the prerequisites for use and was applicable to several actionable decisions. The seasonal forecast had limited use and value due to a perceived low quality, low confidence and that the farmers found it difficult to apply such coarse temporal and spatial scale information to local scale decisions. Any climate change information was accessed through mass media and had such limited detail and relevancy to the area that its value was negligible. Without significant improvements in detail and presentation the value of the longer term forecasts will remain low because of relevancy and understanding issues as well as the inability to apply these longer term information in its current form to decision making, causing the forecasts to not reach their potential usefulness and value.

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Chapter 1: Introduction

1.1 Introduction

Botswana is aiming to achieve complete food security for the country, with a focus on achieving cereal production self-sufficiency within 10 years (Botswana Ministry of Agriculture 1991; Benza 22 January 2010). Large scale arable farming in Botswana is dominated by a reliance on precipitation, as there are very few perennial surface water sources large enough to accommodate large scale irrigation (Batisani 2010). The weather and climate that can occur over Botswana is highly variable, especially with regards to rainfall amounts and events, and this variability may increase with projected climate change (Omari 2010). Both between and within season rainfall variability is closely associated with an uncertainty of agricultural yield over much of southern Africa and this variability has the potential to increase as the impacts of climate change become more apparent (Cooper et al. 2008). Weather and climate prediction information could include anything from an hourly weather forecast to a three month seasonal forecast and further into the future to include climate change projections.

As rain fed agriculture is directly dependent upon weather and climate events, it is reasonable to assume that any information that forecasted weather and climate would be highly significant to the planning and decision making of the farmers. Studies have shown that forecasts have the potential to greatly decrease the effects of climate variability in agriculture (Marshall et al. 2011; Patt & Gwata 2002). There is concern from the creators of forecast information that forecasts are not used to their full potential by the receivers of the information, despite the potential benefits and high levels of awareness (Johnston 2008; Marshall et al. 2011). Issues over the reliability of the information, whether it is accessed, fully understood and trusted enough to use in decision making processes will lower the degree of use, and as a result will lower the value placed upon the information by the user. A detailed study on the use and value of climate prediction information can potentially allow for improved information once the users' preferences are known.

There is concern that the forecasts being developed are not being utilized by the intended users to their full potential. This lowers the value of the information and provokes interest into whether the forecasts are worthwhile and reliable enough for their intended users. A better understanding of the use of forecasts in decision making processes can help to gain insight into why there is a low adoption of the forecasts to aid adaptation to climate variability and change (Marshall et al. 2011). This research therefore focuses on the use of weather and climate forecasting information by large scale farmers in Botswana. An investigation into the degree of uptake and use of forecasts by farmers can provide a better understanding of any issues that users have with the forecasts, including reasons for not adopting the forecasts in decision making. The large scale farmers in Pandamatenga were chosen for this research due to their significant contribution to crop production in Botswana. This is aided by their comparatively better climate and soils to the rest of Botswana and high levels of government assistance.

Some previous studies have shown that issues such as a lack of understanding, trust and an availability of alternative options often cause a decrease in forecast use, and therefore a diminishing value placed upon the forecasts (Patt & Gwata 2002; Phillips 2003; Sherrick et al. 2000; Marshall et al. 2011). Shorter term forecasts, such as weekly weather forecasts have been found to be more applicable to decision making than the longer term climate forecasts, though the desire of farmers for longer term forecasts remains high despite lack of attributable use (Johnston 2008). Climate change information has been found to have very little use in Africa due to a lack of detailed and relevant information (Ziervogel & Zermoglio 2009).

1.2 Research Aims and objectives

This thesis aims to assess the value of weather and climate forecasts for agricultural planning and management decision making, using the case study of commercial farmers in Pandamatenga. The research will analyse key factors that determine access and use of the forecasts, with the value being determined by the degree to which each forecast is taken up and used. In so doing this thesis will critically analyse how effective and useful the different forecasts are to the farmers. The three main forecast types that will be assessed are weather forecasts (no more than 2 weeks), seasonal climate forecasts (3-6 months) and climate change information (decadal or more).

The aim will be achieved by discerning several different aspects of how farmers in Pandamatenga interact with the forecasts as detailed in the following research objectives:

- Assess the importance of weather and climate related risks that farmers perceive themselves to be vulnerable to
- Analyse the accessibility of the different forecasts including barriers limiting the ability to access forecast information
- Analyse the uptake and use of forecast information to decision making
- Highlight factors inhibiting or contributing to the use of different forecasts

1.3 Organization of the Study

This research study is divided into seven chapters, with the first chapter being this introduction which presents the aims and objectives of the study.

Chapter 2 is an extensive literature review that includes background on vulnerability definitions with relation to climate risks and climate change; a breakdown of the types of forecast information that dominate the study; an interrogation of the valuation of forecasts including relevant previous studies' findings or issues; and concluding with an overview of information user cognition and how this influences decision making. The chapter concludes with a framework highlighting the key points for analysis of in the results.

Chapter 3 is a detailed outline of the study site. It includes overviews of Botswana agriculture, the Pandamatenga farming area and the dominant climate over the region, including potential climate change impacts.

Chapter 4 presents the methodology used for the research. It outlines the data collection methods; a profile of the survey respondents; ethical considerations and research constraints.

Chapter 5 is the first chapter to analyse the results of the survey. It includes the farmers perceived risk profile and potential importance of forecast information to the farmers. It interrogates how the farmers access forecasts including issues experienced when attempting to access the forecasts.

Chapter 6 completes the analysis of the results by addressing the remaining factors necessary for forecast use which include the perceived quality of and confidence in the forecast and the ability to choose different courses of action. In so doing this chapter assesses how the forecasts are used and concludes with a descriptive valuation of the forecasts accessed by the farmers.

Chapter 7 completes the study by displaying a summary of the key findings in a graphical format aligned to the framework devised in chapter 2. It provides further insight into the value of the different forecast information with a discussion of two important factors that differentiate the usefulness and value of the weather and seasonal forecasts. The chapter concludes with implications and insights for future research and understanding as well as providing a few limitations to the study.

Chapter 2: Literature Review

2.1 Introduction

Climate prediction information can be a beneficial resource to aid planning in any sector that is climate dependent (Hammer et al. 2001). Short term adjustments in behaviour and practices can reduce the risk of impacts from climate variability and can be achieved through actions based on forecasted climate information (Dilley 2000). Simply producing climate information is not enough to meet the assumption that it is beneficial. Information such as climate forecasts needs to meet certain requirements in order to be considered valuable and worthwhile for initial and continued production (Luseno et al. 2003). These requirements shall be interrogated further into this chapter.

First, it is necessary to locate the need for climate information in the literature on vulnerability and risk reduction. The production of climate information is purposefully done with the aim of reducing users' vulnerability to climate impacts. Hansen (2002) states the purpose of production of climate information as:

“The emerging ability to provide timely, skilful climatic forecasts offers the potential to reduce human vulnerability to agricultural impacts of climate variability through improved agricultural decision making, to either prepare for expected adverse conditions or take advantage of expected favourable conditions.” (Hansen 2002, 310).

The assumption being that provision of information, which can be used to improve management, planning and adaptation decisions can allow for proper preparation against potential risks as a result of undesirable climatic conditions. The climatic risks that may face farmers are numerous and are influenced greatly by the time of year and geographical location of the farms. Details from the literature of what climatic risks farmers in Pandamatenga are vulnerable to are unpacked in section 3.2.

2.2 Vulnerability

The vulnerability concept has become a dominant thread through much of the scientific literature relating to climatic variability and change (Adger 2006). Vulnerability has several definitions that fit for different contexts (Adger 2006; Smit & Wandel 2006; Luers et al. 2003). One definition is the susceptibility to harm of a system to any shocks or stresses that it may be exposed to (Adger 2006; Batisani 2011; Luers 2005). The vulnerability to any stresses or shocks is often characterized by the magnitude and frequency of the shocks, as well as the sensitivity and adaptive capacity of a system (group of people, individual, household, nation etc.) to deal with any external influences which they are at risk to (Adger 2006; Hampel 2006).

Weather and climate events such as drought, extreme temperatures and heavy rain can be hazards that farmers may be vulnerable to now and into the future (Handmer et al. 2012). It has often been stated that variable yield production in rainfed agriculture is directly linked to variable rainfall experienced, and as such farm yields are vulnerable to any adverse rainfall occurrences (Abdullahi et al. 2008; Cooper et al. 2008). Climate change has the potential to increase this vulnerability as the potential for incidences of adverse climate conditions are projected to increase for much of the world, including southern Africa (Cooper et al. 2008).

Reducing vulnerability can be achieved by increasing the coping and adaptation mechanisms or strategies available (Adger et al. 2005). This forms part of the adaptive capacity, which is defined as the ability of a system to change in order to accommodate hazards it is at risk to and to increase its coping range (Adger 2006; Luers et al. 2003). Adaptation is a process or action that helps to manage a hazard in order to enhance the ability to cope and reduce vulnerability, or even take advantage of a changing situation (Smit & Wandel 2006). Coping strategies are often designed to mitigate negative effects but not often to take advantage of any potential benefits, mainly because they are thought of as support strategies to get by with (Cooper et al. 2008).

Activities reliant on weather and climate, such as rain fed farming, are directly vulnerable to changes or unexpected events in their weather and climate pattern. Cooper et al. (2008) discuss the three different types of coping strategies which can be implemented by farmers, namely: Ex ante; in

season; and Ex poste. They go on to discuss the benefits and choices of these coping strategies, finding that Ex ante strategies if applied correctly can be the most beneficial as they are not reactionary, but are planned in advance due to certain stimuli available to the farmer, rather than a spontaneous required reaction to adverse conditions (Cooper et al. 2008). It has been argued that an increase in information provision about hazards and risk can increase the adaptive capacity of people by allowing them to prepare accordingly to a known hazard (Hampel 2006; Smit & Skinner 2002; Risbey et al. 1999). Preparation can be done ahead of time if the information provided meets the requirements necessary to act upon, such as relevant, accurate, lead time. This is however difficult when considering climate change, as specific knowledge on impacts are often unknown when looking further into the future (Fussel 2007; Ikeme 2003).

Barriers which limit the options and ability for adaptation highlight the dynamics within a system that have a negative influence upon any attempted adaptation. Barriers to adaptation are essentially anything that may limit, inhibit, or challenge the ability to adapt (Arnell & Charlton 2009; Jones 2010; Ikeme 2003). Important to this study are barriers that would hinder the access and use of climate information to the farmers. Jones (2010) classifies human and informational barriers as one of her main subdivisions of adaptation barriers, arguing that knowledge and human cognition of the information is one of the most important barriers to adaptation currently. This has also been considered by Adger et al. (2009) as part of the social limits to adaptation. Behaviour and cognition of farmers is unpacked later in section 2.6, in terms of how they influence the use of climate information.

Climate change has the potential to increase people's vulnerability to climate and weather impacts (Adger et al. 2003). Increased or increasing vulnerability can push a person's or system's coping ability beyond its threshold of being able to cope (Smit & Wandel 2006). Breaking these coping thresholds could increase in frequency into the future as an increase in frequency and magnitude of threats and stressors could breach these thresholds. Knowledge provided by climate information on current and projected changes to climate variability should promote management practices to reduce vulnerability (Hansen 2002).

2.3 Types of Climate Information

Although there are almost inexhaustible amounts and types of weather and climate data available, this thesis concentrates on the use of three main types: daily or weekly weather forecasts; seasonal climate forecasts; and climate change projections. These focus on short term, medium term and long term prediction information respectively and given previous studies' results were assumed to be accessible and usable by the farmers in Pandamatenga. Each of these information types is designed, created and presented in different ways, which shall be unpacked below.

2.3.1 Weather Forecasts

Weather forecasting is the shortest time period of forecasting considered here. Weather forecasting can be thought of as the use of available technology and knowledge to predict the state of the atmosphere and its variables for a specific location at a specific time in the near future (Pasini 2005; Engelbert 1997). Observations on the atmosphere are measured by station data, weather balloons, satellites, etc. to provide the initial atmospheric conditions and this data is coupled with a model (Engelbert 1997; Stern & Easterling (eds.) 1999). Generally, numerical models are used to assimilate all of the data used to create a forecast by way of solving equations of how the atmosphere acts, though a forecaster's knowledge and experience are still required for interpreting the weather events and variables inputted and outputted from the model (Pasini 2005). Numerical models work by simulating how the atmosphere will change as time progresses from an initial state input, following the laws of fluid and thermodynamics which control most of the dynamic atmospheric processes (Pasini 2005; Engelbert 1997). The resulting output from the model provides the basis for a skilled weather forecast.

It is possible to skilfully predict the weather for up to ten days in advance, but the accuracy of the forecast will diminish after about five days. The reason for the accuracy of the forecast diminishing after a few days is due to the chaotic nature of all the dynamic variables and their processes in the atmospheric system, which are not fully understood by meteorologists (Pasini 2005). A forecast is considered to be skilled if it was created using equations and models as an objective approach,

rather than an unskilled forecast which is a subjective educated guess by a forecaster (Engelbert 1997).

2.3.2 Seasonal Climate Forecasts

Seasonal forecasting is a relatively new concept compared to weather forecasting, coming to prominence as a result of the extreme El Nino conditions existing in the early 1990's (Dilley 2000; Jones et al. 2000). Its output is different from a weather forecast in that it does not deliver predicted weather events, and in fact individual weather events at specific times and locations may contradict the seasonal forecast (Johnston 2008). A seasonal forecast output is a range of probabilities of temperature or rainfall as compared to a climatological average, displaying predicted probability of above, near or below normal conditions for the upcoming month or season (Goddard et al. 2001); (Johnston 2008; Vogel & O'Brien 2003; Stern & Easterling (eds.) 1999). As seasonal forecasts are predictions of climate rather than weather, they deliver and use averaged statistics of climate variables (Stern & Easterling (eds.) 1999; Pasini 2005). Though some forecasts are deterministic, the general trend is to create probabilistic forecasts, to predict what is likely to occur rather than making claims over what will occur (Pasini 2005).

Seasonal forecasts were initially developed using statistical and empirical models engaging with large amounts of historical data. However, more dynamical approaches have taken dominance in recent years with Global Circulation Models (GCM) being used to extend the forecast range (Vogel & O'Brien 2003). These GCMs are being coupled with observed or modelled data on sea surface temperature (SST), historical climate data, satellite information or a combination of these, and are run multiple times to create an ensemble output for the forecast (Johnston 2008; Vogel & O'Brien 2003; Washington & Downing 1999). GCMs are discussed further in the next section on future climate projections. The shift from statistical models to dynamical models occurred to allow for incorporation of the statistical data sets and atmospheric circulations, especially with regards to boundary conditions such as SST (Stern & Easterling (eds.) 1999). Boundary conditions, those that occur on the lower levels of the atmosphere interacting with surface conditions have been found to play a large role in seasonal climate variability and circulation, with SST being the most dominant of these boundary conditions as SST anomalies can persist for up to 6 months (Johnston 2008; Barnston et al. 2005; Vogel & O'Brien 2003; Goddard et al. 2001). In several cases seasonal forecasters use the

El Niño Southern Oscillation to aid in modelling SST; however this is not always applicable in all locations, but has shown strong correlation to climate variability in southern Africa (Vogel & O'Brien 2003; Johnston 2008). The output from all of these components enables the prediction with increased skill of certain variables, mainly temperature and rainfall, for future months, creating a seasonal climate forecast (Goddard et al. 2001; Barnston et al. 2005).

2.3.3 Future Climate (Change) Projections

Over the last few decades the study of the future of climate has become one of the largest researched topics in the world (Pachauri 2004). This has partly been driven by the Intergovernmental Panel on Climate Change (IPCC) to determine whether the climate is being changed by anthropogenic forcings, mainly in the form of Greenhouse Gases (GHGs). Research has established that anthropogenic global warming is the leading cause of rapid climate change, which has the potential for large scale effects and impacts across the globe (IPCC 2007). This research is important for rainfed farmers because climate change could lead to changes in their current climate and its variability as the global hydrological cycle is expected to increase in strength and speed due to increased warmth and therefore potentially increased water vapour in the troposphere (Held & Soden 2006; Sheffield & Wood 2008). This could result in a change of rainfall and temperature extremes as global circulation patterns are projected to change (IPCC 2007).

Most of these projections are driven by the creation of Global Circulation Models (GCMs). GCMs are computer based models that calculate climate states for certain time and spatial scales based on mathematical equations, which replicate the physics and dynamical interactions of the climate system including the atmosphere, ocean, land (biosphere) and cryosphere across the world (Hewitson & Crane 2006; Tadross et al. 2009; Collier et al. 2007; Pasini 2005). It is because of their holistic data that GCMs are considered the best method for understanding climatic processes; how these have changed in the past; and how these may yet change in the future (Collier et al. 2007).

GCMs have a coarse horizontal grid resolution; a standard grid scale is around 300km x 300km due to the computational resource requirements to run them at any finer resolution. It is for this reason that regional models are created to specifically tackle smaller scales than that of GCMs (Pasini 2005).

Another method which is proving quite popular for tackling smaller scales is that of downscaling GCM data to regional or even point areas. This is done dynamically into regional climate models (RCMs) or statistically into station data points (Charles et al. 1999). In downscaling, the relationships between small scale variables and the larger scale model output are assessed and these relationships are applied to a model output to enable a higher resolution output (Williams et al. 2010). Often this downscaling is done empirically, which refers to the assumption that the same synoptic scale states are present in the future as were present in the past. This is referred to as stationarity, and means that past statistics of the climate are applied to the GCM to develop future downscaled outputs (Hewitson & Crane 2006).

As models are unable to simulate the entire atmosphere, due in part to computer capabilities and scientists not fully understanding all of the atmospheric dynamics, simplification or parameterization of some variables exists within the models (Charles et al. 1999). An example of this is spatial homogeneity of grid scales which as described are very large and therefore can cover a varied landscape, with varied interactions with atmospheric processes. Validation is required as a measure to gauge the integrity of the model output or how well the models can simulate the real world (Reichler & Kim 2008; Charles et al. 1999). There is no single method for validation but it involves the verification of the calculations and inputs that comprise a model to assess how well the model can make sense of the real or observed (Reichler & Kim 2008). Model simulation of mean climatology and variability is assessed, involving large scale features and circulations of the seasonal cycle, including the ITCZ in the right place, precipitation when and where it should be and SSTs changing as they should (Pierce 2004; Reichler & Kim 2008). Future data is assessed on how well model projections relate to what scientists believe will happen, given knowledge of atmospheric processes and driving factors (Charles et al. 1999; Pierce 2004). In other words, does the model project what is expected to happen given the science? Most often models are very good with temperature but struggle to simulate precipitation, mainly due to grid scale sizes and the multiple possible causes of precipitation over such a large area (Snyder et al. 2007). Proper validation ensures that the models' simulations and their outputs are accepted as suitable tools for aiding the understanding of the atmosphere and can provide projections for future climate.

2.4 Value of Forecast Information

It is not enough to purely assume that forecasts are valuable. Valuation is necessary to determine the necessity of forecasts in order to justify the research and development costs of creating and producing an operational forecast (Doll 1971). In order to achieve this, it is necessary to design methods in which a valuation can be completed, as a forecast alone has no intrinsic value, but requires a value to be placed upon it by those that use it (Murphy 1993). Early evaluations placed value purely on the quality of the forecast, assuming that an accurate forecast would determine actions resulting in economic gains, and therefore only inaccurate forecasts could have little value (Doll 1971). However more recent literature has found consensus on the need for a more holistic valuation of forecasts, placing more emphasis on value being gained through decisions and actions influenced or changed by an accessed forecast (Luseno et al. 2003; Hansen 2002; Murphy 1993; Jones et al. 2000; Thornes & Stephenson 2001; Sherrick et al. 2000). The two main ways in which a valuation of forecasts can be achieved are a quantitative economic (financial) valuation, and a qualitative criteria approach.

Some studies argue that valuing forecasts based on how decisions made using the forecast lead to financial profits is the most important result (Thornes & Stephenson 2001; Mylne 2002). In this case a simple cost to loss ratio can be used, based on monetary terms of the cost to repair or prepare against adverse weather events, requiring precise prior knowledge of probability of adverse weather occurrence (Thornes & Stephenson 2001). This will result in valuation of the forecast based on whether it needs to be used or not if a repair or prepare option is selected. However it does not take into account that it requires the use of a very accurate forecasts that pertains directly to the decision required in order to be able to make this valuation. This, by default, gives the forecast value, due to its accuracy and direct correspondence of information contained within the forecast to the decision made. This value is not a direct financial one.

A more precise financial measure is an economic comparison of differing outcomes between scenarios where one farmer has no access to a forecast, and another farmer has access to a forecast and uses it (Sherrick et al. 2000). The argument here is that the forecast will gain value if the farmer that uses it achieves a greater profit than the farmer that does not use it, should all other variables be equal. However these assessments are based around the farmers having complete prior

knowledge of historical climate and potential probabilities of the climate and its variables are for their location, even in the case where no prediction is provided (Sherrick et al. 2000). As a result, these analyses form part of the issues highlighted by Roebber and Bosart (1996) and Murphy (1993) surrounding a prescriptive or descriptive approach to value analysis. The prescriptive approach involves an ideal situation of how an accurate forecast should be used to always make optimal decisions for maximum returns, showing the potential value of the forecast (Roebber & Bosart 1996; Vogel & O'Brien 2003). The descriptive approach is based on a real world description of how forecasts are actually used, though because this does not always use optimal decisions it tends to result in lower economic benefits, but will show the actual economic value of a forecast (Roebber & Bosart 1996; Vogel & O'Brien 2003). Analyses of a forecast's economic value, such as that in Sherrick et al. (2000), rely on the prescriptive approach and not the descriptive approach.

Due to difficulties and issues in the above approaches to valuing forecasts, some literature has tried to explore a more qualitative and descriptive approach to analyse real world scenarios. These do not place so much emphasis on attaining an actual value figure, but instead resort to a more holistic understanding of forecasts. These assessments require several determinants as well, in order for forecast value to be measured and realized.

Murphy (1993) argues that there is a tiered system for forecasts to attain three different types of goodness, which is summarized in table 2.1. He describes type 1 goodness as Consistency of the forecast, being how forecasts are developed using all the tools and knowledge that are available to the forecaster including models, technology, observations and knowledge of area, in order to deliver consistently rational and logical forecasts (Murphy 1993). As described above, this can also be referred to as consistently using skill to develop forecasts. Consistency in developing forecasts is fully controlled by the forecaster, with the exception of any format constraints such as length or style of the forecast (Murphy 1993). Type 2 goodness is described as the Quality of a forecast, which is how similar the forecast is to the real world observations made at the time for which the forecast specifies (Murphy 1993). Type 2 refers to aspects of the forecast such as accuracy and reliability, which is only partly controlled by the forecaster, as even a highly skilled forecast may differ from real world observations (Murphy 1993). Type 3 goodness is the most important type of goodness for this study as it is termed the Value of the forecast, which is any real benefits realized by use of the forecast to guide or influence choices among alternative courses of action (Murphy 1993). This of

course can be done using economic models and statistics, or through more descriptive methods, such as behavioural studies. Type 3 goodness is out of the forecaster's control, as it is achieved through the use of a forecast by end-users in certain situations, and the decision to use the forecast ultimately rests with the user (Murphy 1993). Forecasters may attempt to influence this decision if there is any interaction with them, but the decision is still with the user.

Type	Name	Definition
1	Consistency	Correspondence between forecasts and judgements
2	Quality	Correspondence between forecasts and observations
3	Value	Incremental benefits of forecasts to users

Table 2.1 - Forecasts Types of Goodness (Murphy, 1993)

The valuation of a forecast can occur ex ante or ex poste, measuring the actual value against the expected value (need for) of the forecast (Murphy 1993). Applying ex poste assessments to weekly and seasonal forecasts can be done as observational data relevant to forecasted time can be made available. However it would be necessary to apply an ex ante assessment to any climate change information and rely on expected value of the information as the actual time pertaining to the projections will not pass for several decades in some cases.

Luseno et al. (2003) take the valuation of forecast information further, issuing three conditions for attaching value. The first condition is that the correlation of information to its value is tied to the amount of information provided, as well as the skill and quality of the information (Luseno et al. 2003). In other words good skill and value will increase information value. The second condition is that confidence in the information is required to warrant a change of attitude towards information and actions based upon it (Luseno et al. 2003). Increasing confidence should make the user trust the information more, leading to acceptance of the reduction of probable distribution of weather which the forecast predicts. The chances of certain weather occurring can be thought of a probability distribution, and a good forecast will lessen this distribution by skilfully predicting the most probable weather occurrences. This acceptance of reduced probable distribution is needed for the third condition which is that decisions, ideally optimal decisions, will depend upon the degree of

perceived change of the probable distribution of weather as a result of the forecast's influence (Luseno et al. 2003).

So it can be asserted that attaching value of any kind to a forecast requires that forecast to be influential enough to provoke a changing of decisions and actions by a user in order to improve their management and reduce their vulnerability to climate and weather risks (Hansen 2002). In order for a forecast to be able to influence decisions it needs to meet certain requirements or prerequisites which shall be unpacked further in the next section.

2.4.1 Prerequisites for Forecast Use

The skill leading to reliability and quality (also called credibility) of a forecast is one of the most important requirements that a forecast needs to meet in order to be considered operational and trustworthy enough to base decisions upon (Luseno et al. 2003; Murphy 1993; Orlove et al. 2004; Patt & Gwata 2002). Inaccurate forecasts will lead to an inability to assess values based on the consequences of a decision as few users will risk a trial and error approach to an unreliable forecast (Jones et al. 2000; Patt & Gwata 2002). Analysing these characteristics of a forecast is necessary for the predictions made to gain value (Sherrick et al. 2000). Thorough analysis requires a verification to gauge a forecast's quality. Thornes & Stephenson (2001) argue that there are a number of factors that make up a forecast's quality, namely: reliability, skill, accuracy, resolution, sharpness and uncertainty. No single verification scheme could appropriately verify all these factors together, so require a detailed verification of each factor to give a holistic detailed verification of quality (Thornes & Stephenson 2001). Jones et al. (2000) argue that quality verification will always render a forecast inaccurate due to inherent uncertainty especially in seasonal and climate change forecasts. This is due to our imperfect understanding of all the chaotic and dynamic physics processes of the atmosphere, which lead to model biases (Jones et al. 2000). The quality of a forecast includes its style and resolution which will have an effect on the information that the forecast delivers. Use of forecast information can also be constrained by the style of the information, such as its spatial scale, which for climate predictions can be too broad for effective scale use, as well as potentially being too difficult to interpret without access to an expert or explanation along with the forecast (Vogel & O'Brien 2003).

In order for forecasts to be used, they must be received by users, either by individuals accessing, or tailored communication and dissemination (Luseno et al. 2003; Vogel & O'Brien 2003). Potential communication constraints include any language barriers across diverse regions and more importantly the different types of media used for delivery and access by producers and users respectively (Hudson & Vogel 2003). The timing of this accessing of the forecast is also very important as it will determine the lead time for which the user is able to make decisions and actions based on the forecasts. Receiving even the best forecast at the wrong time is of little use and leads to a lowering value of the forecast (Orlove et al. 2004). The more lead time available is generally considered to be better as the user has more time to interpret and use the forecast; however it is also known that accuracy of the forecast decreases with an increased lead time due to the uncertainties mentioned by Jones et al. (2000) in the paragraph above (Orlove et al. 2004). Hansen (2002) states that the increased uncertainty of using a forecast to make decisions several months in advance leads to the need for preparing for a range of possibilities, which is often done at the expense of reducing potential productivity. This is also known as the conservative approach, which is employed by many farmers as a result of uncertain forecasts (Hansen 2002; Sherrick et al. 2000).

It is essential for a user to have confidence in the forecast, as without confidence there would be no trust and no use (Luseno et al. 2003; Lybbert et al. 2007; Hammer et al. 2001). Confidence is gained through the user appreciating how the forecast may reduce their vulnerability to climate or weather risks, and is closely linked to the above discussed quality and understanding of the forecast (Hudson & Vogel 2003). Confidence, even in an accurate forecast may take time to increase, even several years in some cases (Luseno et al. 2003). Increasing the confidence in a forecast often requires the forecast to change the mind-set of the user to expect a different climate and weather scenario than what their prior beliefs dictate, presenting new information for which to make choices upon (Lybbert et al. 2007; Patt & Gwata 2002). Confidence in the information received can change how users process information, and change the level of value that is placed upon the information, leading to different choices and actions (Lybbert et al. 2007; Luseno et al. 2003). Often for this to be achieved a forecast must present a vastly different probability distribution of weather or climate from what the user perceives to be the norm, as people will often update their beliefs and confidence due to extremeness of the information (Luseno et al. 2003; Lybbert et al. 2007).

The last requirement for a forecast to gain value has little to do with the actual forecast, but more on the situation of the user. There needs to be a more than one course of action available to the user to achieve benefits of using the forecast (Luseno et al. 2003; Murphy 1993). This is because of the value in a forecast being gained when the forecast influences a decision or change of action, but a situation without options renders even the best forecasts invaluable as action changes are unavailable. Often users lack the flexibility to adjust management practices due to their own complex situation, such as those in South East USA researched in Jones et al. (2000). This can occur due to a lack of assets, such as finances or mechanisation, hindering their ability to adapt or change practices, as is often the case with small scale farmers (Roncoli et al. 2009). This factor though is very particular to different situations, as Phillips (2003) found differing results to the above. It was found that assets do not appear to hinder the use of forecasts in small scale farmers in Zimbabwe, but may influence the access to forecasts (Phillips 2003).

Table 2.2 summarises the above information on prerequisites for use.

Prerequisite for Use	Justification
Access	For forecasts to be used they must be available / accessible / disseminated. (Luseno et al. 2003; Vogel & O'Brien 2003)
Quality	Forecasts must be skilfully created, delivering reliable and credible information. Often verification is necessary. (Orlove et al. 2004; Patt & Gwata 2002)
Confidence	The users of forecasts need to trust the information (closely linked to quality as perceived accuracy increases trust). (Luseno et al. 2003; Lybbert et al. 2007)
Situation of user	There need to be alternative courses of action (options) available to the users of forecasts so that the forecast can influence choice. (Luseno et al. 2003; Murphy 1993)

Table 2.2 - Summary of Prerequisites for Forecast Use

2.5 Using Climate Change Information

Projected future climate change information is technically a forecast, be it an extended forecast spanning several decades. However, it has its own sphere of literature due not necessarily to the type of information it entails, but also on the repercussions of that information and how people react to it. Climate change literature deals with different terms due to the differing timescales and responses. The previous section on forecasts explained the value of forecasts to making choices and management plans in response to users current climate variability and potential weather events. Managing responses to climate change information is considered different as it entails longer term responses to the changing climate and associated impacts requiring more permanent management decisions, extending beyond coping for a few months or single season. This is known as adaptation. The use of climate change information is perhaps not at the stage where a proper valuation of the information can be achieved due to minimal use (especially in Africa), and continuous updating and validation of model outputs (Ziervogel & Zermoglio 2009). Some focus is given to literature surrounding information and knowledge uptake by so called 'end-users' as well as knowledge issues which represent barriers to adaptation. The section ends with literature that deals with the communication and dissemination of climate change information in order to promote adaptation.

Work in climate change adaptation has become a highly invested and important research field with several different theories and ideas (Adger et al. 2009; Thornton & Manasfi 2010). The IPCC has assessed the published literature on climate change adaptation and developed a definition as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Klein et al. 2007; Smit & Wandel 2006). Some studies have tried to redefine the term, either to encompass a broader field (Moser & Ekstrom 2010), or to try and make it more focused (Jones 2010). Essentially all definitions address the need for actions and strategies to moderate harm and reduce any potential vulnerability in response to a changing environment (Fussler 2007; Smit & Wandel 2006; Thornton & Manasfi 2010) and most studies fall back to the IPCC definition for its simplicity and broad use.

Adaptation can be divided into two parts, proactive and reactive (Jones 2010; Ikeme 2003). Reactive adaptation occurs after an event and is the most common form of adaptation due to the knowledge gained from the event as well as the anxiety that such an event or worse may occur in the future

(Fussel 2007). Reactive adaptation is therefore not done through use of forecast information, but as a consequence of a weather hazard and accumulated climate change. Proactive adaptation is more difficult to undertake as you do not have the exact knowledge of how climate change may or may not affect you, especially with events decades into the future. However though the impacts are uncertain, it is still important to concentrate on proactive adaptation to increase preparedness for impacts into the future (Ikeme 2003). Robust climate change projections can be used for proactive adaptation by recommending policy or infrastructural changes in anticipation to expected changes (Fussel 2007).

Until recently most researchers considered it essential that in order to adapt to climate change robust knowledge on the direction of change and of regionally specific impacts of climate change was needed (Adger et al. 2005; Adger et al. 2003; Arnell & Charlton 2009; Burton et al. 2004; Downing et al. 1997). They argued that without climate change knowledge communities, individuals and states could not adapt accordingly, because they would not know what they were adapting to, and therefore may adapt poorly, expensively or for completely wrong impacts (Ziervogel et al. 2008; Smit & Skinner 2002). This poses a serious challenge to adaptation as model projections do not accurately predict specific hazards or risks, but are able to simulate overall climate regimes into the future, which is often on too big a spatial and temporal scale for specific adaptation planning use (Ziervogel & Cartwright 2011). Uncertainty in climate change projections is similar to that of forecast information, based around already explained model imperfections as a result of a not fully understood complex atmosphere and its processes. This is potentially more important for climate change projections as these issues could become more apparent the further the model runs into the future (Ziervogel & Zermoglio 2009). As discussed in the section detailing climate change information, models are validated before their projections are broadcast showing that they can capture synoptic climate dynamics. But this is at the grid-scale level, and the uncertainty becomes more apparent when extrapolating from projections for smaller localized scales. Increased confusion and uncertainty can arise due to there being several different GCMs created with different inputs and calculated dynamical interactions which can create a large envelope of projections (Collier et al. 2007).

Uncertain climate change information can limit the ability to adapt, as it is difficult to know the correct adaptation response. The study of barriers or limits to adaptation is a growing and important

field of study. This is an important field as it highlights dynamics within sectors that have a negative influence upon attempted adaptation. As stated in section 2.2 on vulnerability, barriers to adaptation are essentially anything that may limit, inhibit, or challenge the ability to adapt (Arnell & Charlton 2009; Jones 2010; Ikeme 2003).

There are arguments to move beyond the barrier of uncertainty within climate change projections and to promote adaptation despite it (Dessai et al. 2009; Patt & Dessai 2005; Patt et al. 2005). It is important to know how different sectors view climate change knowledge and how they use future projections to inform their decisions; in contrast to how their current knowledge of past climate and weather events informed their past decisions (Adger et al. 2009); (Lobell et al. 2011; Weber 2006; Patt & Schröter 2008). By knowing how sectors and people interact with climate change information, assessment over why adaptation does or does not take place can be undertaken (Adger et al. 2009; Fussel 2007). Dessai et al. (2009) state that sectors should move beyond the probabilistic uncertain projections and use what certain knowledge there is to inform adaptation decisions; much the same as adaptation and planning for natural disasters such as earthquakes is done.

A few authors argue that a main reason for knowledge and information being such a strong barrier to adaptation is that people either do not have access to the information or are unable to properly interpret and use it once they are exposed to it (Adger et al. 2009); (Ziervogel & Zermoglio 2009; Ziervogel & Cartwright 2011; Grothmann & Patt 2005). In this argument people often are unable to adapt due to their low self-efficacy (Adger et al. 2009). In other words, people often will underestimate their ability to act and adapt, or believe that it should be done for them, usually by government (Grothmann & Patt 2005; Marx et al. 2007; Patt & Schröter 2008). But a potential solution to this issue is increasing people's knowledge about climate change and how it may affect them. Increasing knowledge and understanding around climate change impacts should increase peoples' self-efficacy, as their understanding of projected impacts would increase their motivation to act, and knowledge of what can be done would improve (Adger et al. 2009; Frank et al. 2011). The issue of motivation to act will be covered in section 2.6 next.

Central to countering this knowledge and understanding barrier therefore is the continual improvement of communication and dissemination of climate change knowledge to those who need it to adapt. Certain studies have shown that there is overall a severe deficiency in climate change

knowledge dissemination resulting in ineffectual or no adaptation (Patt & Schröter 2008; Ziervogel & Zermoglio 2009; Dilley 2000). Some of the main issues behind lack of knowledge, use and dissemination are down to practical layout of the information and who produces it. Most climate change information is produced as model outputs which have very coarse resolution and are projected several decades into the future, with downscaled data for many areas, especially in the developing world being limited (Ziervogel & Zermoglio 2009; Pidgeon & Fischhoff 2011). Agents who are intended to use this information are often unsure of how to interpret model outputs and get lost within the jargon of 'ensembles, downscales, averages, extremes', etc. (Ziervogel & Zermoglio 2009; Ockwell et al. 2009).

A comprehensive study conducted within the United Kingdom by Holmes and Clarke (2008), used detailed interviews with people in government departments, NGOs and individuals into the use and uptake of climate change science. They found that government reports and published science papers were often difficult to find or access due to cost or lack of public access resources such as peer reviewed journals. They also found that across all interviews most people found that science papers were too focused and technically detailed and so could often not be used adequately to adapt or inform policy. The findings of this research recommended a need to compromise the imbalance between researchers and policy makers, perhaps having an interpreter to evaluate research findings and deliver knowledge to policy makers (Holmes & Clark 2008).

Research done in Africa by Ziervogel and Zermoglio (2009) found similar results to those of Holmes and Clark (2008). They found that African farmers were unable to use climate change information effectively due to lack of capacity to interpret and understand the information. Similar issues of access to information were also noted. They were able to recommend a need for scientists, donor and users of information to cooperate more in order to integrate climate research into development strategies and bridge the gap between what scientists produce and what 'end-users' need (Ziervogel & Zermoglio 2009).

Improving communication is an emerging field of study which is beginning to take previous studies and apply social science to findings to deliver recommended improvements. Essentially any form of communication with regards to science should look at a number of factors, mainly understanding of information, emotions or values of the agents to use the information and their overall behaviour

when previously given information, or how they act when given information (Ockwell et al. 2009; Grothmann & Patt 2005).

2.6 Cognition and Climate Prediction Information

Considering how important the mental processes of users are in affecting their processing and use of any climate prediction information, it is interesting to briefly unpack this literature further. Some of this has been touched on in previous sections of the review. Merely having awareness and access to climate predictions is not enough to achieve usage of the information. It is necessary to encourage use of information through behavioural and mental processing changes (Meinke et al. 2006; Patt & Gwata 2002; Frank et al. 2011). In order to induce a behavioural change it is necessary to disrupt a farmer's expectations by providing information which will demonstrate how the outcomes of regular or normal actions are inadequate (Patt & Gwata 2002). Firstly though, it is important to understand how and what drives decision making amongst farmers and other users of forecast information and how new information could change thought processes to drive adaptation.

Several studies argue that a first step to being able to base decisions upon information is that the information itself must have certain conditions attached to it, outlined as salience, credibility and legitimacy (Cash et al. 2002; Meinke et al. 2006; Johnston 2008). The relevance of information, or that the information provides enough to base decisions upon, is known as its salience, and may require the information to be developed to include several variables and their interactions across rooted disciplinary zones (Cash et al. 2002; Meinke et al. 2006). The technical aspect of the information, what we have already described as its quality, can also be termed as its credibility, referring to accuracy and validity (Cash et al. 2002). It should be noted that this can be achieved not just from precision of the information but also through proper communication and engagement (Meinke et al. 2006). The legitimacy of the information has to do with the perception that the information has the interest of the users in mind and is unbiased in its development; often this can be achieved through user participation in development (Cash et al. 2002; Meinke et al. 2006). It is important to not overlook this level of trust, as farmers are likely to act on information when it is produced by sources they are familiar with and already know (Hansen 2002). Information should be developed with these three factors built in to achieve levels of trust and confidence necessary for users to believe that the information is good enough to rely on.

There are some arguments in the literature in favour of the specific use of models and frameworks in order to predict and explain behaviour and decision making process. Gifford et al. (2011) explain several of these theoretical frameworks relating to environmental change, surmising that behavioural patterns tend to follow social norms and values of specific groups making it difficult to implement any framework to all groups. Bayesian decision theory has been implemented to estimate probabilities and decisions over risk (Doll 1971; Lybbert et al. 2007; Patt & Schröter 2008). Bayesian rules dictate that decisions should minimize risk by the use of a statistical approach quantifying trade-offs between costs and benefits of decisions, by use of changing probabilities due to information uptake (Harsanyi 1978). In this way risk should be minimized through selection of an action in which the expected loss due to potential risks is minimized (Harsanyi 1978; Lybbert et al. 2007). As Bayesian theory deals with probabilities in uncertain conditions it has been theorized to be effective when dealing with climate prediction information (Lybbert et al. 2007). Though using statistical methods and set frameworks to estimate how people deal with probabilities of risk can be theoretically sound, often this does not describe people's behaviour and choices in practical situations (Patt & Schröter 2008; Orlove et al. 2004). Often it has been found that people use their memories, emotions and other mental shortcuts, such as heuristics (experience based techniques e.g. trial and error) to guide their decision making (Patt & Schröter 2008; Grothmann & Patt 2005; Johnston 2008; Patt & Gwata 2002).

Gifford et al. (2011) argue that though the information may be good enough, there are psychological barriers which determine why people do not act on climate information, with particular reference to climate change. With seven categories broken down and explained, they provide an exhaustive list of reasons why people do not act on climate change information. Most of their discussion relating to use of information centres on limited cognition, or understanding of the information, and a lack of perceived risk. This limited cognition is important as failure to understand a forecast leads to non-use of the forecast, or using it incorrectly (Patt & Gwata 2002). This is defined as cognitive illusions, which are errors committed without knowing, which arise from an inability to deal with and understand probabilities, uncertainties and risk (Nicholls 1999). Simplifying the forecast can solve this, but will open questions over whether the forecast provides enough information to allow for decision making (Patt & Gwata 2002).

Using a more attitude based approach, several studies argue that the main determinant for adaptation is motivation to act by users (Grothmann & Patt 2005; Gifford et al. 2011; Roncoli 2006; Frank et al. 2011). This can be directly linked to risk perception, as severity of risks will often motivate users to act upon them (Grothmann & Patt 2005). This is often due to past experiences of loss (risk experience), and can be driven by perceived self-efficacy driving behavioural change to achieve an outcome which will remove the risk (Frank et al. 2011; Gifford et al. 2011; Grothmann & Patt 2005). Grothmann and Patt (2005) propose that motivation can be driven by the difference between what a person expects to happen (actual value) and what a person wants to happen, or more specifically, does not want to happen (nominal value). The larger the difference between actual and nominal value will result in more motivation to act to ensure that nominal value is met by actual value (Grothmann & Patt 2005). This can be influenced by the above mentioned self-efficacy, or subjective ability and need to act, coupled with the objective ability to act, such as access to resources and choices (Grothmann & Patt 2005; Patt & Gwata 2002). Once motivation to act has been established, there will be different decision making models, or biases.

It has been argued that farmers tend to not follow a rational economic approach similar to a cost benefit analysis, which is orientated by weighing decisions against the final outcome (Patt & Gwata 2002; Suarez & Patt 2004). Decisions are evaluated and considered good based upon the final outcome, maximising the outcome means the decisions were good (Suarez & Patt 2004). Rather farmers are more cautious in their decision making, choosing what is needed, not basing them all upon maximising economic returns, but on meeting an acceptable return (defined subjectively) while guarding against loss (Patt & Gwata 2002). This is known as functional rationality, or bounded rationality, and is important as it includes decision making to reach acceptable outcomes in situations with limited amounts of information (Jones 1999). In the case of farmers, limited information could be uncertain forecasts that require decisions to be based upon in order to produce an acceptable yield. It is also noted that rationality can be lost due to cognitive influences (Heuristics) such as emotions, values or beliefs over the information (Jones 1999; Nicholls 1999).

Another cognitive influence that has been shown to affect forecast uptake and use are that of dissonance and regret. It is argued that previous use of forecasts that do not accurately predict the actual weather that occurs can lead to the regret of use by the users (Nicholls 1999). This occurs, for example, when a forecast may predict an adverse weather event, such as a heat-wave, and the

farmer takes precautions to protect his crops which cost money and reduce productivity. Should the heat-wave then not occur, the farmer will regret taking the precautionary actions as a result of the forecast's prediction. It has been found that regret is increased with an increase in the actions which divert from regular farming practices (Nicholls 1999; Johnston 2008). Regret of using a forecast which does not accurately conform to actual events can influence the user into not continuing to use that forecast to influence decisions.

There has been some discussion on how peoples' cognitive biases can influence their decision making with uncertain information and risk scenarios. Often when it is clear that any action will lead to a loss people are disposed to make no decisions, in order to avoid regret and responsibility for losses (Suarez & Patt 2004; Patt & Schröter 2008). This Omission bias can be so strong that no action is taken even in a case when no actions will definitely lead to a negative outcome (Patt & Schröter 2008). This lack of action to change a negative situation is closely linked to another bias termed the status quo bias. This is apparent when people are disinclined to modify their current state of affairs (Suarez & Patt 2004). Often the status quo bias is closely linked to the conservative approach of decision making, with regards to negating losses at the expense of maximising gains. This can be because often individuals view the probabilities of losses higher than the probabilities of greatly increased gains (Suarez & Patt 2004). A big issues with regards to incorporation of forecasts in a population that displays a status quo bias is that often the receptivity of new information is low (Suarez & Patt 2004). The only way to change and deliver decisions that lead to actions away from a risk, is when it is absolutely sure that all salient results of an action will be positive, leading to demonstrably good outcomes; this is the Action bias (Patt & Schröter 2008). Achieving an action bias due to forecasts would require the forecast to provide with certainty that non action would lead to clear losses, in order to increase motivation away from a risk scenario.

2.7 Conclusion and Framework

The above literature has been combined into a framework into which the results of this study can be inputted in order for a structured analysis to be completed. The framework is dominated by the literature surrounding the usage of forecasts, both the prerequisites and the value that is gained through use. The analysis of these aspects will be crucial for understanding the situation of farmers in Pandamatenga with regards to forecast use. The analysis of the results through this framework

will be able to provide the details necessary for a valuation of climate prediction information based upon use. The framework is not designed as a conceptual framework covering all aspects of forecast production and reproduction. It is a basic assessment framework to aid in the analysis of information valuation based upon the above literature review, such that loss of value can be identified and isolated to specific reasoning.

The framework is diagrammatically represented by figure 2.1. The top box of the framework shows that valuation of forecasts for this study is based upon the uptake and use of the forecasts. It will be necessary to analyse the prerequisites for use as they will determine the ability of the farmers to use the climate prediction information. The prerequisites for use relate directly to the forecast and need to be achieved to allow for forecast use. Lastly, as highlighted in section 2.6, the decision making or cognitive bias of the farmers will also influence the degree to which the prediction information is incorporated into use. This framework and its associated literature will be incorporated into the analysis of the results from this research detailed in later chapters.

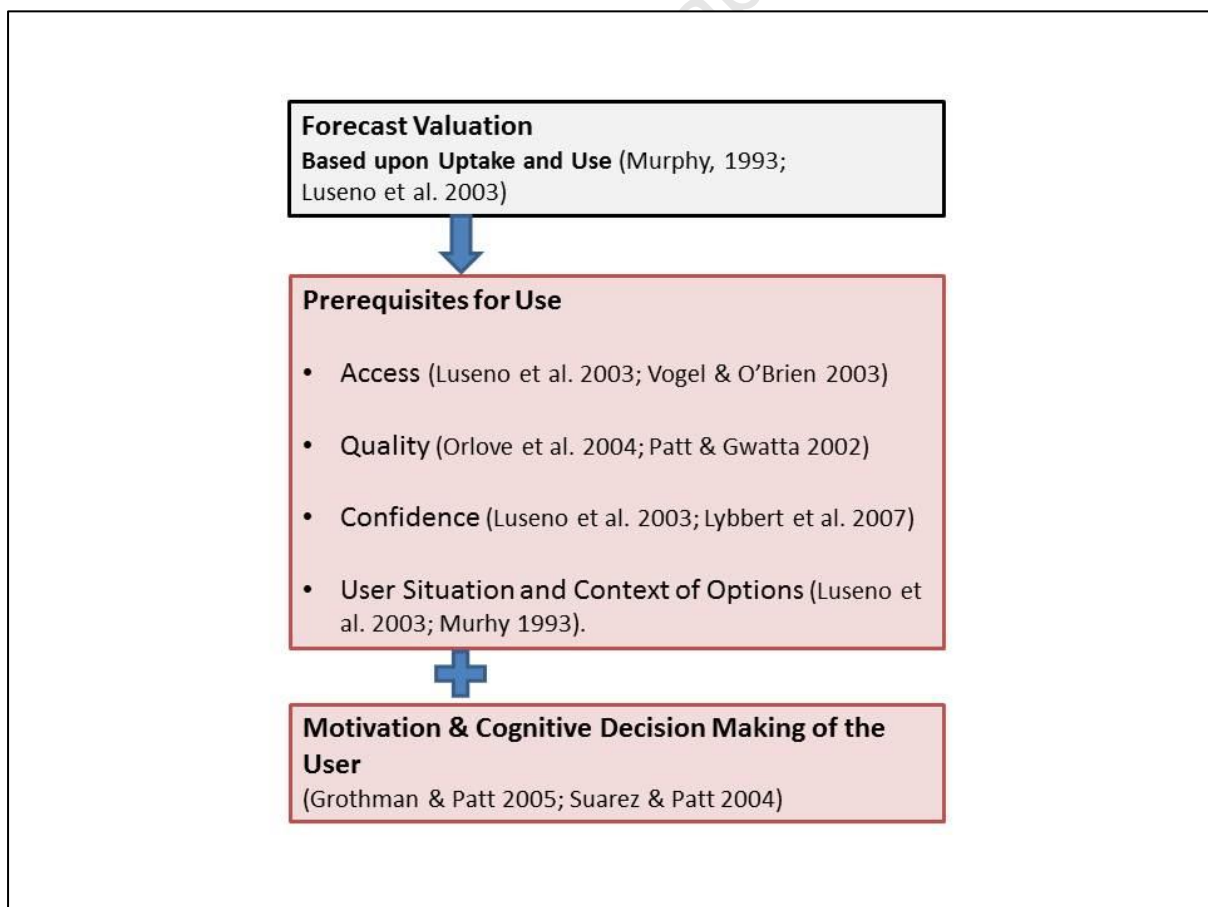


Figure 2.1 – Structured Analysis Framework to Input Results to Identify Gaps in Value

Chapter 3: Study Site Profile

3.1 Introduction to Botswana Agriculture

Commercial arable farming in Botswana has been supported by the government since independence in 1966, all the while aspiring to achieve food self-sufficiency. The first official agricultural policy was only developed and published as the National Policy on Agricultural Development in 1991. It came about after several studies were conducted to assess the performance and needs of agriculture within Botswana throughout the 1980s. The policy acknowledged the impossibility of achieving complete food self-sufficiency and so the new policy aim was food security at the household level in place of food self-sufficiency (Ministry of Agriculture 1991), focusing on increasing the capacity of households to access enough food, irrespective of what is produced within Botswana (Chipanshi et al. 2003). In this way the government would remain committed to increasing agricultural productivity and to ideally become self-sufficient in crops that are suitable to be grown in Botswana, but acknowledging the need for the import of foods that Botswana is not suitable to produce (Moroke et al. 2008). This change came about with the acknowledgment that Botswana, due to its climate, soils, surface water availability and other factors is not suitable for many different crops.

Despite significant efforts, the arable agriculture sector has been under-producing and is still below expected targets of produce, currently producing approximately 20% of total food needed (Benza 22 January 2010; Moroke et al. 2008). In 1999 agriculture contributed 2.9% of the GDP, with arable agriculture only being approximately 20-30% of this (Kgathi et al. 2003). This is in part due to a low availability of suitable arable land, only 6% of the country, which is otherwise desert savannah, and only 1% of the land is under annual cultivation (Moroke et al. 2008). Despite the poor performances of the arable agriculture, it still provides income to 50% of the population of 1.7 million, mainly small scale farmers (Moroke et al. 2008). This is one of the leading reasons that the government continues to promote arable agriculture.

Arable farming in Botswana is constrained by a number of factors including: the climate, having low and unreliable rainfall; recurrent drought; lack of credit for farmers; inadequate infrastructure and technology in many areas; and poor management (Kgathi et al. 2003). However it has the potential

to make a sustainable contribution to the economy, in the form of employment, food and foreign exchange through the production of several crops including: sunflower, sorghum, maize, beans and millet (Moroke et al. 2008). Foreign exchange is dominated by the export of sunflower to mills outside of Botswana, mainly in South Africa. Several government initiatives have been put in place to achieve this, including the creation of the Botswana Agricultural Marketing Board (BAMB), the Integrated Support Programme for Arable Agriculture Development (ISPAAD) and the National Master Plan for Arable Agriculture and Dairy Development (NAMPAAD).

NAMPAAD and ISPAAD are similar and are concerned with the overall improvement of crop production in order to reduce reliance on imports. Both initiatives deal with increasing commercialization of agriculture through provision of technology and mechanization for smaller scale farmers, while improving employment through commercialization and facilitating access to credit and extension services (Ministry of Agriculture 2008; Ministry of Agriculture 2000). Both of these initiatives came about due to the failures of previous endeavours by the Ministry of Agriculture, and are aimed at fixing faults in previous initiatives that were unsuccessful.

BAMB has been in existence since just after independence and so is not a new initiative, but has already been successful in aiding arable farming in Botswana. As the marketing board is a parastatal company it is responsible for the Strategic Grain Reserve of the country and is highly involved in the supply and distribution of agricultural inputs (e.g. seeds, fertilizers and mechanized assistance), as well as purchasing produce at fixed prices from contracted farmers (Botswana Agricultural Marketing Board 2010). BAMB plays an important role with large scale commercial farmers who are mostly contracted to BAMB. This according to BAMB means: "BAMB searches for markets for specified crops and contracts farmers to produce them at agreed prices and quantities. This helps to minimize exposure to price risks due to price fluctuations dictated by market conditions" (Botswana Agricultural Marketing Board 2010, 5). This contractual farming does help the farmers with a guaranteed buyer of their produce at a pre-determined price, meaning that they are not so exposed to market fluctuations throughout the year. BAMB can provide farmers with a place to store produce immediately after harvest, else the farmers have to store their produce themselves which can be several hundred tonnes of produce (Mokwena et al. 2003). However it is possible for BAMB to dictate lower than market prices for produce, which was an issue in the past but has not been a

large issue since 1999 when they increased their sorghum price by 66% over one season (Kgathi et al. 2003).

3.2 The Climate of Botswana

The climate of Botswana is semi-arid though parts of the country, mainly north and north-east, can receive substantially more rainfall than the semi-arid Kalahari Desert that dominates most of the country. The rain season coincides with a very hot summer where average summer temperatures in extreme years can reach up to 40°C (Moroke et al. 2008). Typically the rain season will start around the middle of October and end around the middle of March but can last into May, with the Peak rain months being December through to February (Batisani 2011; Vossen 1990). Rainfall amounts for the whole country differs greatly from around 250mm in the South West, to over 650mm annually in the north-east. A whole country average is 500mm annually, with a potential standard deviation of 225mm (Alemaw et al. 2006). High temperatures and low humidity over summer can lead to potential evaporation exceeding rainfall by a factor of 3-4 in the north-east (where Pandamatenga is located, see figure 3.1), and even higher further south (Vossen 1990).

Such a high standard deviation of the rainfall amounts (half total rainfall) is indicative of the high variability experienced over the region. Rainfall occurs in a very irregular pattern, usually as localized showers or thunderstorms, which can result in a very large spatial and temporal distribution of precipitation (Moroke et al. 2008). The variability is more than aptly described by Batisani and Yarnal (2010, 483) as “spatial and seasonal variability exacerbated by the unpredictability of rainfall from year to year, within the year, and even during a single rainfall event.” This means that dry-spells within the season, or even larger scale droughts and drought conditions are common place within Botswana. In the past country wide droughts generally occur 1 in every 10 to 15 years, though in season dry-spells occur much more frequently (Moroke et al. 2008; Batisani 2011).

There are two dominant synoptic factors that control most of the climate across Southern Africa. These are the semi-permanent high pressure, sub-tropical systems occurring over the south-east Atlantic and south-west Indian Oceans (Batisani 2011). Both these systems create a large-scale, persistent subsidence over the region associated with anti-cyclonic conditions with divergence

reducing moisture inflow from tropics and oceans, resulting in the semi-arid conditions (Batisani 2011; Cook et al. 2004).

These subsidence and anti-cyclonic conditions are broken up during the rainy season as the Intertropical Convergence Zone (ITCZ) moves further south into Southern Africa, settling over Zimbabwe and Mozambique from January to March (Cook et al. 2004). The ITCZ brings low level moisture convergence to the region allowing for precipitation events to occur. The large scale precipitation occurrences are a result of Tropical Temperate Troughs (TTTs) with their associated cloud bands, that are able to form off the ITCZ and are responsible for between 50-90% of precipitation from November to March over Southern Africa (Cook et al. 2004; Batisani 2011). It has been established that TTTs are the dominant summer rainfall producing weather system over southern Africa and that total interannual variability of rainfall is directly linked to the variability in frequency and positioning of TTTs (Ratna et al. 2012).

The Botswana climate is dominated by anti-cyclonic, dry synoptic conditions which are interrupted by only a few synoptic conditions that support precipitation. As a result the presence or absence of just a few favourable precipitation conditions can make the difference between years of drought or abundant rainfall (Batisani 2010). This is what makes the region so susceptible to droughts or dry conditions.

3.3 Pandamatenga Commercial Farming Area

Pandamatenga is a small village located in the north east of Botswana, 100 km south of the Zambezi River. Commercial farming was reintroduced to Pandamatenga in 1983, after a hiatus since 1957, while still under the policy of food self-sufficiency (African Development Bank 2008). However farms were unable to produce as expected, achieving an average of only 0.5-1.4 metric tonnes per hectare of sorghum, while they were expected to produce 1.7-1.9 mt/ha (African Development Bank 2008). This average was still much higher than the national average of only 0.3 mt/ha of sorghum, and while they are considered to be under-producing the Pandamatenga plains still produced 65% of all sorghum in Botswana, while only contributing 32% of the land planted in 2005 (Abdullahi et al. 2008; African Development Bank 2008).

Pandamatenga has been supported by the Government of Botswana for commercial farming since 1983, as it is widely recognized as having the potential to be the most productive dry land (rain fed) arable farming area in Botswana (Abdullahi et al. 2008). This is mainly due to its comparatively higher than average rainfall, put by several studies at 600mm per year with a lower standard deviation of 196mm, and its comparatively more fertile soils (Abdullahi et al. 2008; Kgathi et al. 2003). The temperature of the Pandamatenga area is more amenable to farming as it has less extreme heat than the rest of the country as well, with mean maximum temperatures of 34°C in summer to 26°C in winter (Abdullahi et al. 2008). The soils over the Pandamatenga plains are vertisols, which are very fertile for crop production as the plains are ancient alluvial lake beds (Alemaw et al. 2006).

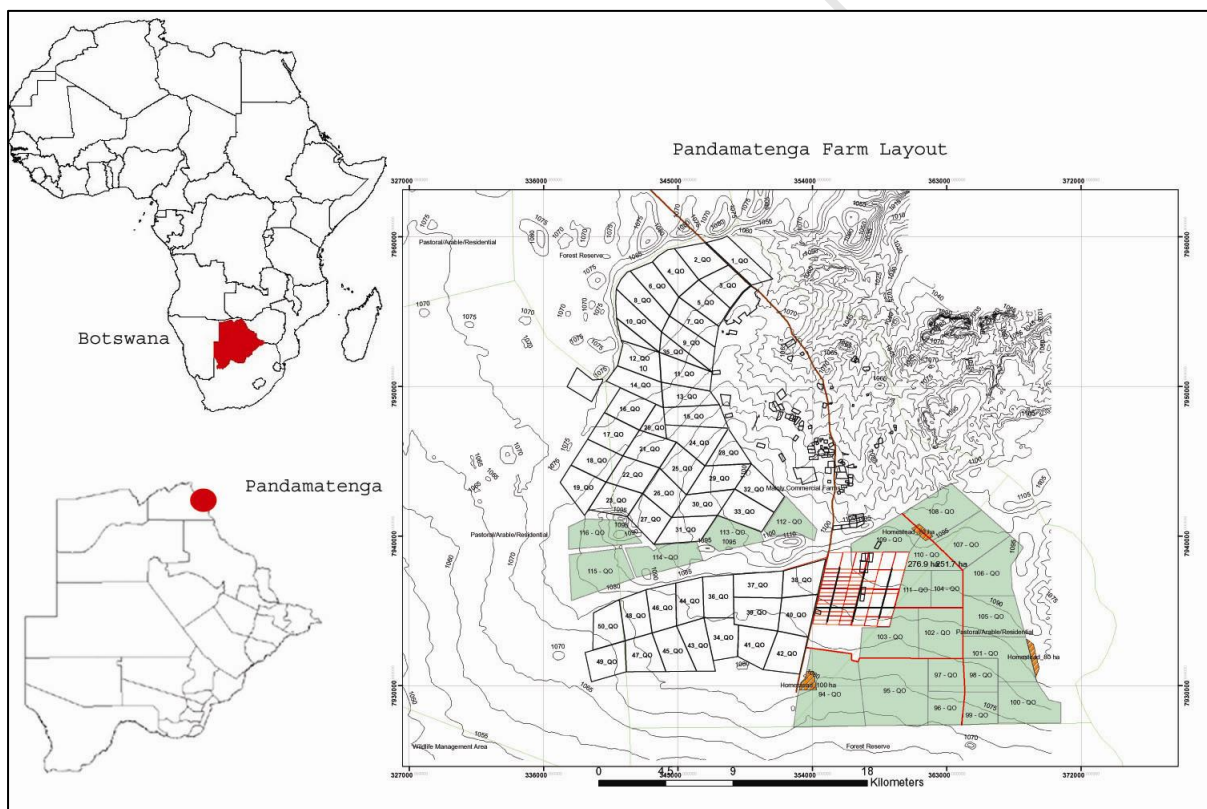


Figure 3.1 - Pandamatenga Location. Existing farms with black borders and new farms targeted for development shaded green (African Development Bank 2008)

Pandamatenga farms cover an area of 25 000ha currently with 25 commercial scale farmers in the area, with more farms being divided in the south east (Khukhutha 2012). The average farm size is

500ha. Most farmers have one or two crops on their farm per season with the main crops cultivated are sorghum, sunflower and beans of different types (Khukhutha 2012). The introduction of legumes has been motivated by the Ministry of Agriculture after pioneering them on their research farm. Legumes are good nitrogen fixing plants due to the bacteria on their roots and when alternated with sorghum this can save money on artificial fertilizers. The legumes also have a shorter growth season, meaning they use less soil moisture and so will be potentially less affected by a variable rain season (Khukhutha 2012).

The low productivity of the Pandamatenga farmers prompted assessment studies in the late 1990s and early 2000s which concluded that productivity was limited by frequent flooding of the vertisol plains and the lack of all-weather roads allowing farmers access to their fields throughout the year (African Development Bank 2008). The susceptibility to flooding is caused by the soil type and very low topography slope profile resulting in poor drainage. Vertisols can absorb large amounts of water, but once they become saturated the top layer will seal, stopping infiltration causing the pooling of water on the surface, which will happen often after a large rain event after the soil is already moist (Kgathi et al. 2003; Alemaw et al. 2006). These flood events often happen at the start of the growing season, in the peak summer months.

To counter and adapt to these flood events the Government of Botswana, in conjunction with the African Development Bank, has intervened with a new roads and drainage project. This project is designed to provide useable roads all year round through the farms, as well as aid in the removal of excess water from farms during flood events (African Development Bank 2008). Construction of the project started in August 2011, aimed to be completed in 3 years. This is a significantly large adaptation project by the government. It includes 161km of all-weather gravel roads, 220 km of primary drains, 147 km of drains in the fields and 800 km of contour banks throughout the plains in order to harness and control the flow of water, reducing flooding and soil erosion (African Development Bank 2008). Upon completion of this project, production in Pandamatenga is expected to rise to between 1.5-4.0 mt/ha, depending on rainfall, reducing imports, creating employment and potentially allowing for diversification into agroindustries (African Development Bank 2008).

3.4 Potential Climate Change to Botswana

Farming in Botswana is already struggling from a climate that is less than conducive for encouraging and assisting food production. At the UNFCCC's 16th Conference of the Parties (COP16) Botswana's Deputy Minister of Environment, Wildlife and Tourism, Thabang Leslie Bothshome (2010) stated that Botswana was already suffering from the effects of climate change in the form of heat waves, highly unreliable rainfall and widespread recurrent drought. He further highlighted the need to understand climate change science to determine the socio-economic impacts of climate change and the implications of this for sustainable development (Botshoma 8th December 2010).

Most reports on climate change impacts on Botswana are quite general and based on large scale General Circulation Models (GCMs). Expected changes are a decrease in precipitation and an increase of temperatures, consistent with other semi-arid areas (Chipanshi et al. 2003). Temperature is expected to increase by 1 -3 degrees Celsius by 2050, which will have a knock on effect towards higher potential evapotranspiration (Omari 2010; Wingqvist & Dahlberg 2008). With regards to future rainfall trends, though uncertain, there is a consensus around projected decreases with increased variability, with the potential for greater localization of events as well as a shortened rain season (Omari 2010; Wingqvist & Dahlberg 2008).

Studies investigating the amount and distribution pattern of rainfall across Botswana show results that suggest climate change is already occurring, with decreasing total rainfall amounts associated with a decrease total days with rain over the past 30 years (Batisani 2011; Abdullahi et al. 2008; Kachale 2009). These results are similar to analyses done on projected climate change for Botswana, with a decrease of total rainfall (Wingqvist & Dahlberg 2008; Chipanshi et al. 2003). Immediate impacts of decreasing rainfall in an already semi-arid climate are water shortages and increased frequency of drought occurrences into the future, associated with increased variability (Batisani 2010). Using the 30 year long term average of rainfall amounts and distribution it was found that the 10 years from 1998 to 2008 experienced 6 drought years, while the other 4 years experienced localized drought conditions (Kachale 2009).

Figure 3.2 below uses collected rainfall amounts of six major towns and cities in Botswana to create a graph that shows average yearly totals for the country. With the exception of the years 2000 and 2006, which were years with abnormally large rainfall amounts in the south causing widespread flooding, the graph corroborates the above studies showing small decreasing rainfall amounts for much of the decade post 2000. The data is sourced from the Botswana Meteorological Department.

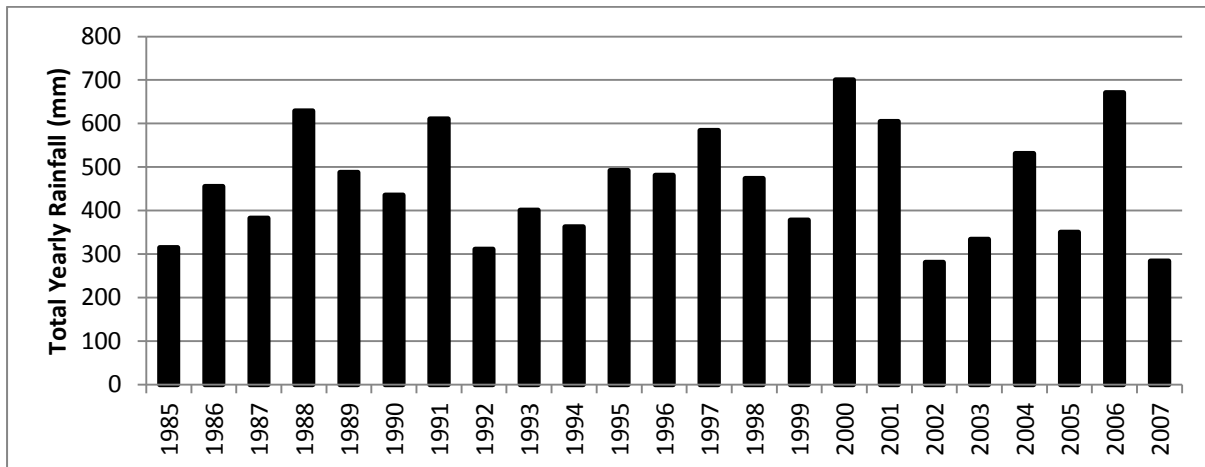


Figure 3.2 - Long Term Historical Rainfall Yearly Totals (MET Data 2012)

The effect that climate change may have on crops could be large depending on the severity of change. Some crops may grow better with increased temperature and Carbon Dioxide amounts in the atmosphere due to increased photosynthesis rates (Rötter & van de Geijn 1999). However maize and sorghum species already show carbon dioxide saturation under current atmospheric conditions, and increases in temperature in Botswana may take these species outside of their optimal temperature range (Rötter & van de Geijn 1999; Chipanshi et al. 2003). There is likely to be increased weed competition due to the increase of carbon dioxide and temperature, as certain grass species have a positive growth impact due to increased carbon dioxide and temperature (Chipanshi et al. 2003). The increased temperature and shortened rain season in Botswana will have an immediate impact on the length of the growing season available to farmers, resulting in lower yields without a cultivar with significantly shorter growth duration (Chipanshi et al. 2003).

The importance of the Pandamatenga Commercial Farming area to Botswana agriculture will increase into the future as the climate of the rest of the country becomes even less conducive to

crop growth. Rising temperatures generally result in an increase in moisture needed by plants to counter the increased transpiration rate (Rötter & van de Geijn 1999). Accompanied by a decreasing amount of rain, soils with higher moisture retention such as those in Pandamatenga will become more important for production as grain production in southern Botswana may produce almost meaningless yields into the 21st century due to their already poor soils and rain totals (Chipanshi et al. 2003).

3.5 Weather and Climate Products available in Botswana

There are multiple weather forecasts available from various media forms in Botswana. The Botswana Department of Meteorological Services (MET) produces weather forecasts which are communicated through Botswana Television (BTV), radio and newspapers. Though it is advertised on their website it is more often than not unavailable or no up to date. Satellite television and multiple internet websites provide weather forecasts for most major urban locations in Botswana as well.

A seasonal forecast is also produced by the MET office, usually released in October and is distributed to MET extension offices and then on to others. This is also stated as available on the website, but at the time of writing the website still displayed the 2008 seasonal forecast. Access to the current seasonal forecast could not be attained prior to research. Figure 3.3 is an example of seasonal forecast as found on the website. Details on how these forecasts are created could not be attained. Other seasonal forecasts that include Botswana in their map predictions include those of the International Research Institute (IRI) and Climate Systems Analysis Group (CSAG).

Climate change data for Botswana is difficult to find beyond general news stories. Actual projections and data could not be found and reliance upon studies that discuss their results without actually presenting their projections was necessary for the discussed research covered above.

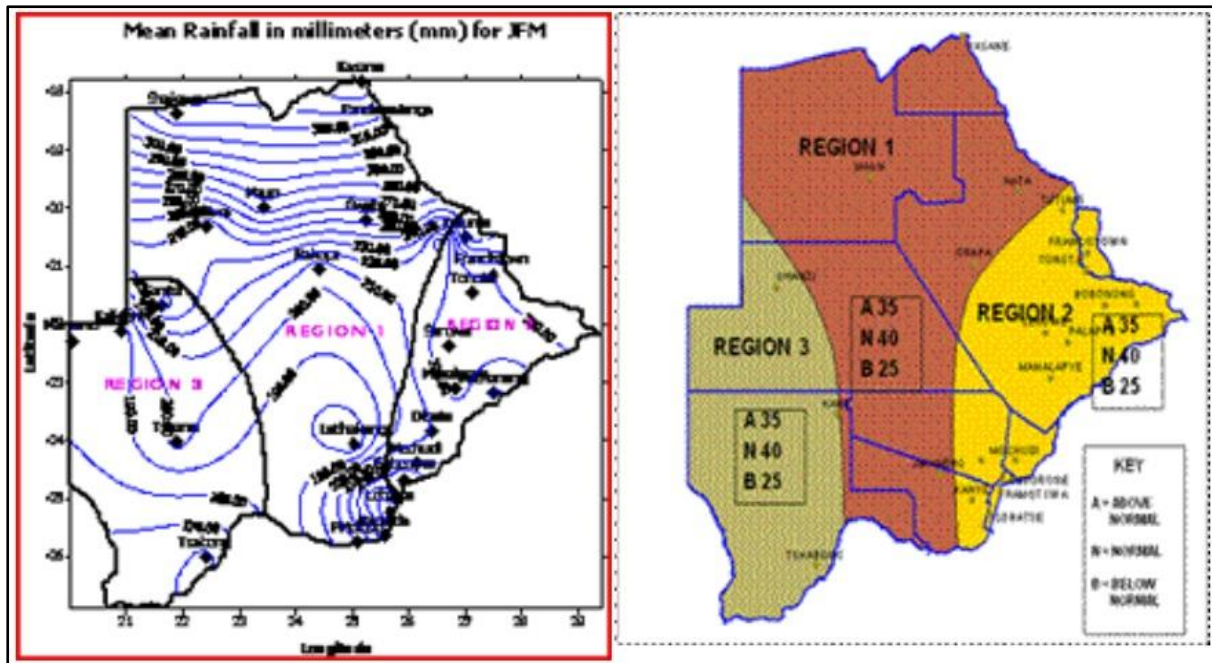


Figure 3.3 - Botswana Rainfall Seasonal Forecast example for January, February and December (Source: www.mewt.gov.bw)

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Chapter 4: Methodology

The methodology employed for this study was designed to determine the degree of use of weather and climate forecasts to commercial farmers in Pandamatenga, Botswana. An assumption of this study was that the commercial farmers in Pandamatenga at least accessed and had knowledge of different forecast types and scales and that these forecasts may have influence over their decision making or planning. The rationale behind determining the degree of use and value of climate prediction information to the large scale farmers in Pandamatenga was done with the information covered in chapter 3 (Study Site Profile) in mind. As Pandamatenga is the main cereal production area of Botswana, the success or failure of achieving food security hinges on the success of Pandamatenga farmers.

Several studies have shown the value of climate prediction information, such as seasonal forecasts in other southern African countries at the commercial farming scale (Hudson & Vogel 2003; Klopper & Bartman 2003; Patt & Gwata 2002; Phillips 2003; Johnston 2008). These studies infer that similar scenarios could and should occur elsewhere; in areas that access to climate prediction information can be assured.

This chapter explains the justification for and design of the method of data collection chosen. The data collection mainly centred on a structured survey to gather descriptive data surrounding the farmers' interaction with weather and climate forecasts. The scope of the survey and profile of the farmers as respondents is explained in detail. Other methods of data collection are explored and incorporated or discarded depending of their determined usefulness for this particular research. Approval for the research, necessary ethical considerations and difficulties in the research are areas included towards the end of the chapter.

4.1 Assessment of Data Collection Techniques

A structured survey for completion by the commercial farmers was the main component of the methodology. Though a few approaches could have been taken, such as open-ended discussions, it

was decided that a structured survey which asked the exact same questions to all farmers would be the most beneficial.

The use of surveys to gather data on climate forecasts, especially around the areas of access and perceptions of usefulness, has been well established in studies around the world, though most focus on one particular forecast and not several different scales. Some work in southern Africa includes: Phillips (2003) used a household survey in Zimbabwe among communal farmers with focus on determined how resources or wealth affect the access and use of seasonal climate forecasts; Klopper and Bartman (2003) used surveys to assess how the timing of receiving a forecast affected its incorporation into decision making of commercial farmers in South Africa; and Hudson and Vogel (2003) used surveys to try determine the perceived value and use of seasonal forecasts in decision making by livestock farmers in South Africa. The results of these studies found that forecasts are only somewhat valuable, and that use is limited mostly by perceived inaccuracy. Outside of southern Africa, Orlove et al. (2004) used a survey with Peruvian fishermen to determine issues over accessing weather and climate forecasts. These studies were all done as an assessment of forecast ability during the expected strong El Niño events of 1997/98 and La Niña of 1998/99. After the severe conditions of the 1992/93 El Niño, it was assumed that weather and climate forecasts could aid in preparation for the similar events expected in the late 90's. Due to the large media coverage of the El Niño and La Niña the studies found access to not be an issue, as most people had access to at least one of the media types used for communication (Phillips 2003; Klopper & Bartman 2003; Orlove et al. 2004).

Survey studies in southern Africa have been completed that did not revolve around El Niño. Ziervogel and Calder (2003) used surveys to apply a livelihoods approach to the use of seasonal climate forecasts in Lesotho. His thesis is very similar to this study, with the survey questions used being styled on Johnston's survey. However Johnston's (2008) study was a controlled study based on direct dissemination of the forecast by him to the farmers each month for a year, in so doing assessing actual forecast use against ideal or potential use.

Surveys have not been used directly to determine access and use of climate change information, for a number of reasons including difficulty of access and understanding of information as well as focus on vulnerability to impacts over information use (Ziervogel & Zermoglio 2009; Gbetibouo 2009).

Holmes and Clark (2008) used an email survey to analyse Government, NGO's and other relevant stakeholders level of awareness, access and use of scientific climate change information, and used their findings to present thoughts on improving communication of such information in the UK. In South Africa, Gbetibauo (2009) used surveys and open ended discussions to determine perception and understanding of what people thought their vulnerability was to climate change, but did not engage with climate change information which would have informed the people's perceptions.

Other methodologies were considered and their application in some studies was assessed for success and potential for application in this research. Ziervogel and Zermoglio (2009) found some success with using individual interviews that were tailored for specific stakeholders with different backgrounds and positions such as those in NGO's and government departments. However when researching the farmers in Pandamatenga it is better to assess their interaction with climate forecast information as one farming community as their profile (location, background, knowledge, etc.) would be very similar. Patt and Gwata (2002) had success with a methodology based around the observation of behavioural attitude changes over a two year period of direct forecast dissemination coupled with educational workshops in Zimbabwe. Their method requires too long a time period for this thesis and is also not an assessment of real world scenario but also a controlled study. Participatory methods have found success in assessing adaptation strategies (Ziervogel et al. 2006). Relevant to this thesis Bert et al. (2006) used decision maps used with maize farmers in Argentina to assess potential for forecasts to assist when particular climate conditions affect them. This assesses potential use of forecasts again, and not an analysis of actual events.

4.2 The Scope and Design of the Survey

Input from some of the above research, especially Johnston (2008), Klopper and Bartman (2003) and Hudson and Vogel (2003) assisted in designing the survey for this thesis. The survey is designed to assess weather forecasts, seasonal climate forecasts and climate change information. It is confined to a very specific population in a small, but very important area. The questions are to gain an understanding of the interaction of farmers and climate information and provide insight for improving available information. A structured survey (Appendix 1) that interrogates the farmers' interactions with types of climate and weather prediction information, and affords respondents limited responses for the most part, allows for a better summary and analysis of responses given. All

findings from the surveys are from the perception or knowledge of the commercial farmer. The survey was designed to gather information enabling the undertaking of the objectives of this study, mainly in order to analyse uptake and use of the forecasts. To overcome previously found issues of understanding and use of climate change information (mentioned above), this survey assumed there would be minimal or no use of climate change information, and limited access to climate change information. The questions for this section were designed in an exploratory fashion, to gain background information (similar to KAP survey explained below).

Addressing these objectives allows for an understanding of the interaction between farmers and climate prediction information and provides insight for improving available information, potentially providing more useful or different information. Informal discussions during farm visits aided in interpreting the survey information gathered and provided additional research data not covered in the survey questions.

The survey was built around the design of a Knowledge, Attitude and Practices (KAP) survey which has been used with regard to health and medical science (Kaliyaperumal 2004; World Health Organization 2008). Looking at knowledge, attitudes and practices provides similar details to the more specific aim of the survey which is to gain knowledge on the awareness, access and use of climate information by farmers. A KAP survey is a good style for this kind of fieldwork as it collects information by way of a representative study on what is “known, believed and done in relation to a particular topic” by a specific target population (World Health Organization 2008). KAP surveys are often exploratory in their information gathering on a unique focus at a specific point in time (Kaliyaperumal 2004). KAP surveys are however usually done on a much larger scale with less depth, to gather fairly rudimentary statistics about a population in order for swift and decisive action, such as prescribe TB education to an area or redirect medical supplies (World Health Organization 2008). Whereas the research for this study is aimed at asking how a specifically small population interacts with a variety of climate information types and sources for analysis. The KAP survey style was useful in designing question structure and specific wording, especially for background questions, however the more in depth questioning broke away from the KAP style by furthering the design to allow for more specific questions on similar topics.

The survey was furthered on from the KAP and Johnston (2009) designs by the direction with which the questions took. The KAP design is quite exploratory, and so was used in the initial background questions, but this survey was furthered by delving into greater detail in each section than simply exploratory data. Though Johnston's (2009) thesis asked similar questions, more focus in this study was given to the access and preferred access of information by the respondents. Topically this survey is different to Johnston (2009), by addressing different forms of information than solely seasonal forecasts, and also breaks away from the end result of Johnston (2009) which was the comparison of the use of seasonal forecasts to determine profit and possible regret after years of being hand delivered a specific seasonal forecast.

Two interviews were conducted outside of the farmer survey, with a Ministry of Agriculture official and the Head of the Meteorological Department both based in Pandamatenga. The ministry official was interviewed to gain background knowledge and gauge ministry involvement with the farmers. The Head of the Pandamatenga Meteorology office was interviewed to cross check the interaction that farmers claim to have or not have with the department, as well as to discover first-hand what information they produce and disseminate to the farmers.

Profiling of the survey occurred amongst colleagues at the University, and later amongst 4 farmers in the south of Botswana. During piloting minimal change was suggested and no major issues became apparent.

A specific statistical programme for analysis of the survey data was not employed. The reasoning for this was that as the maximum number of interviews could only be 25, it was deemed unnecessary for computer based statistical analysis to provide assistance with the results (see next section for number of farmers).

4.3 Study Group and Profile of Respondents

Within the commercial farming community of Pandamatenga there are currently 25 farmers who share 50 farm plots with an average size of 500ha over the central and southern plains of

Pandamatenga. These 50 plots total an area of approximately 25 000 ha. As the plots vary in size and each farmer has a different number of plots farmed, the average farm size is between 500 and 1000 ha, with 5 farms smaller than 500 ha and 5 farms larger than 1000 ha. The main two crops in Pandamatenga are sorghum and sunflower and were planted by the majority of farmers. Only 2 farmers interviewed did not farm sorghum, these had the smaller farms and instead cultivated millet as their sole crop by choice. Legumes such as cowpeas and mung bean were being planted as well, but on a smaller scale than sorghum and sunflower, mainly due to a push from Ministry of Agriculture as a result of their success in the research farm at Pandamatenga.

With regards to age, the farmers are fairly evenly distributed between 30 and 70, with only one farmer younger than 30 years. Only one farmer has been in the area for over 20 years, since 1987, while most others have farmed for between 5 and 20 years in Pandamatenga. Most of the commercial farmers interviewed have had tertiary education of a kind, though some in fields other than agriculture, meaning the overall level of education for the study group is relatively high. The commercial farmers in the area have a relatively comfortable livelihood. Though a bad yield for the year could mean a sizeable dent in income, a good year would mean a large turnover profit. Due to their general wealth it was assumed that the farmers would have a relatively high level of education, which proved to be accurate as all had completed high school and most had some form of tertiary education, though not always related to agriculture. Based upon the literature in which commercial farmers access and interact with climate information without outside encouragement, it was also assumed that the farmers would be interacting with climate and weather forecasts, even though these studies were in other countries (Klopper & Bartman 2003; Phillips 2003). Interaction with different climate prediction information would enable completion of a fairly technical survey and allow for enough data to be collected on this specific area for analysis.

The sampling for the survey was intended to be non-probabilistic, in that 'purposive sampling' method was undertaken (World Health Organization 2008). This was because the plan was to interview as many farmers within the Pandamatenga region as possible. This was due to the estimated small size of the farming population in the area. This would ensure adequate representation and reliability of the survey within this population. As there are 25 farmers in the area, a minimum of 15 interviews was deemed necessary for sufficient amounts of data to be collected, and provide adequate information on the entire population. In fact 19 farmers were

interviewed during the fieldwork in January 2012, all surveys were completed in entirety and so produced 19 surveys as results.

Research in such an area had a few issues which needed to be overcome. Firstly the overall size of the area was difficult to work in, with farmers' homesteads scattered across the boundaries of the 25 000 ha area. The time of year which the research was conducted was during the middle of the rainy season, when farmers were looking to plant as soon as they had enough soil moisture. As such some farmers were often busy in their fields. If enough rain had fallen the fields could be completely inaccessible without a tractor due to deep clay mud of vertisols. This made contacting them on what was already a very poor mobile phone signal, even more difficult. However these obstacles were overcome and all the people in the area were very helpful in assisting with the research.

4.4 Ethical Considerations

Approval for the research was attained from Ministry of Agriculture in November 2011 through contact with the Permanent Secretary. The Ministry Official in Pandamatenga aided with provision of contact details of farmers, maps of the area, background information on Pandamatenga as well as introductions to the Meteorological Office in Pandamatenga and some farmers. The research was conducted during January 2012 in Pandamatenga. Each farmer interviewed spent some time with the researcher in order for the research to be properly explained and for approval to be attained. The majority of the surveys were completed with the researcher present for assistance, but a few were taken away and returned completed later. Every farmer that completed a survey also signed a written consent form and was provided with research approval letters from Ministry of Agriculture and from the University of Cape Town. Anonymity was guaranteed to every farmer, in that their names and personal information would not be published, distributed or made available to any third party. All information gathered would only form data for this particular research, and further use of the data would require approval from all interviewees and the Ministry of Agriculture.

4.5 Conclusion

Surveys have been established as useful tools to gather sufficient amounts of information within a constricted time period, allowing for detailed data for analysis. This survey was completed by 19 commercial farmers, all completed in full and therefore able to be collated and analysed. Though some issues were experienced through the research phase, all these were overcome and did not hinder the information gathering process. These 19 surveys make up the bulk of the research. General discussions with the farmers around the surveys, farm observations during visits and the two interviews from the Ministry of Agriculture and the Metrological Department complete the research project.

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Chapter 5: Results and Analysis - Need, Awareness and Access

This is the first chapter of results and analysis. The chapter starts by outlining necessary background data attained from the surveys, the farmers' perceptions of their risk profile and issues they experience with the weather and climate in Pandamatenga. The chapter then proceeds to analyse how the farmers access their climate prediction information, including any barriers which hinder accessibility. In relation to the framework described in section 2.7, this chapter provides information on access as a prerequisite for use.

The processing of the surveys was done after completion of the entire survey and interview process in order for results to be analysed in their entirety. The data was analysed and is presented complying with the research objectives of the study, as described in Chapter 1. This chapter targets the analysis of the first two objectives, while the remaining two objectives are covered in the following chapter.

5.1 Risks to Commercial Farming in Pandamatenga

A first step to gauging the value of information is to determine whether it is necessary to use the information. Climate forecast information has the potential to reduce vulnerability to adverse climatic conditions by improving management and planning as adaptation (Hansen 2002). Understanding the risks that farmers perceive themselves to be vulnerable to is a first step in assessing whether forecasts are needed and how effective they could be. As discussed in section 2.6, motivation can be the key determinant for action and adaptation to reduce vulnerability to risks (Grothmann & Patt 2005; Gifford et al. 2011). Motivation to act is orientated around the goals of people as a result of what can be termed their relative risk perception or the perceived probability of being exposed to harm (Grothmann & Patt 2005). The higher their relative risk perception is the higher their motivation is to act, and risk perceptions are influenced not just by sources of information but rather by direct experience with loss and harm from hazards (Frank et al. 2011).

The survey asked the farmers what the most important risks are that affect their farming activities. All factors that have a negative impact on their farming practices were included. They were asked to list and rank their top five risks, without guidance or a set of choices, ensuring that all responses were determined by the farmers, enabling climate and weather related risks to be ranked with all other risks. These ranked risks were collated and presented in figure 5.1, displaying a stacked bar graph showing how many times each risk was mentioned by the farmers and the relative level of significance the farmers placed upon each risk. The level of significance is ranked with 1 being the most significant and 5 being the least. The risks listed in figure 5.1 are grouped, with the first seven being weather and climate related, and the remaining risks being considered non weather or climate related. Within these two groups they are also displayed in descending order of significance according to their mentions by the farmers. Some of these perceived risks in the graph are not actual risks, such as planting time, planning and logistics. These are not things that the farmers are risk to, but are issues which need addressing throughout the year, though the farmers considered them to be risks. They were left in the graph as this analysis is of a description of the farmers' perceived risks, and it should be recognised that some of the farmers will not have the same definition of risk as the literature (Hampel 2006). But this is important as these risks need to come from the perspective of the farmers, and providing a definition or examples would have changed their perception of risk and therefore affected their responses.

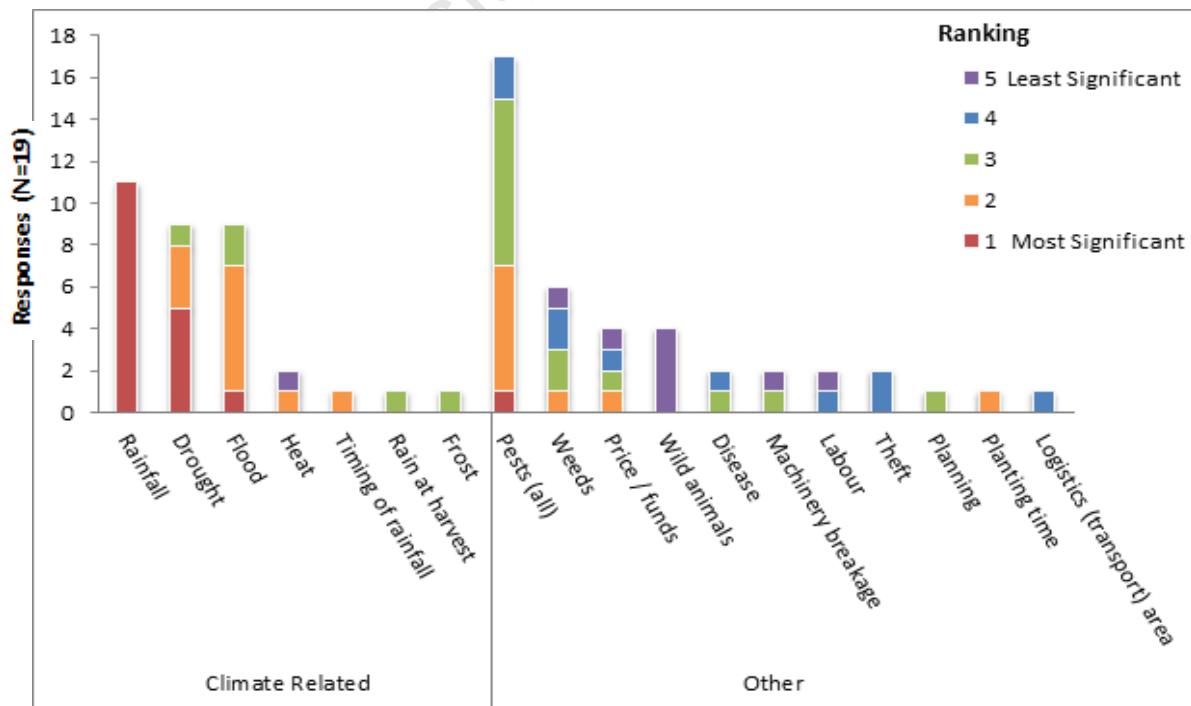


Figure 5.1 - Risks to Commercial Farming in Pandamatenga

It is apparent that pests were mentioned the most, however only seven farmers ranked pests of any kind as their 1st or 2nd most important risk. Though several farmers chose to detach flooding and drought from rainfall, it is clear that rainfall, including onset, lack of, or abundance is the most mentioned risk faced by the farmers in Pandamatenga. Risks surrounding rainfall are also ranked with the most significance, being mostly first or second order risks. The rainfed agricultural practices in Pandamatenga are vulnerable to variable rainfall patterns which can put farming at risk, as covered in detail in chapter 3. It is understandable for farmers to be most concerned with rainfall variables as it is not within their control and is needed (in ideal amounts) at critical times for maximum production. Enough moisture content within the soil is crucial to allow for planting, and once germination has occurred for the fields to not flood and damage young crops.

The farmers know that as rainfall mostly comes from large thunderstorms, extreme localization of rainfall can mean flooding on one farm with some farms suffering poor soil moisture content resulting in crops suffering. Flooding is heightened due to the vertisol soils that dominate the Pandamatenga plains. These soils can absorb large amounts of water and then seal once saturated, creating a large floodplain on which excess water pools.

The Ministry of Agriculture official interviewed concurred with the farmers results. He put flooding and drought / dry spells as his 2nd and 3rd order ranked risks, while his 1st ranked risk was pests of all kinds. He mentioned that Pests took 1st order ranking as they were constant, affecting to a degree every farmer with every crop almost every year. Flooding and dry conditions he argued may not affect every farmer and recently certain actions, such as zero tillage farming, had improved the farmers' ability to manage adverse weather conditions.

Figure 5.2 below shows the first seven risks from figure 5.1 (above) labelled collectively as climate related risks and the remainder of the risks from figure 5.1 labelled as other. The two bars show how many times the farmers mentioned the risks from these two collective groups, and their significance level. By grouping these risks it is seen that although there are fewer climate related risks mentioned than all other possible risks, according to the farmers the climate related risks had a much higher

significance rating. Climate related risks had seventeen (17) 1st ranked risks and eleven (11) 2nd ranked risks as compared to the others with only one (1) 1st ranked risk and nine (9) 2nd ranked risks.

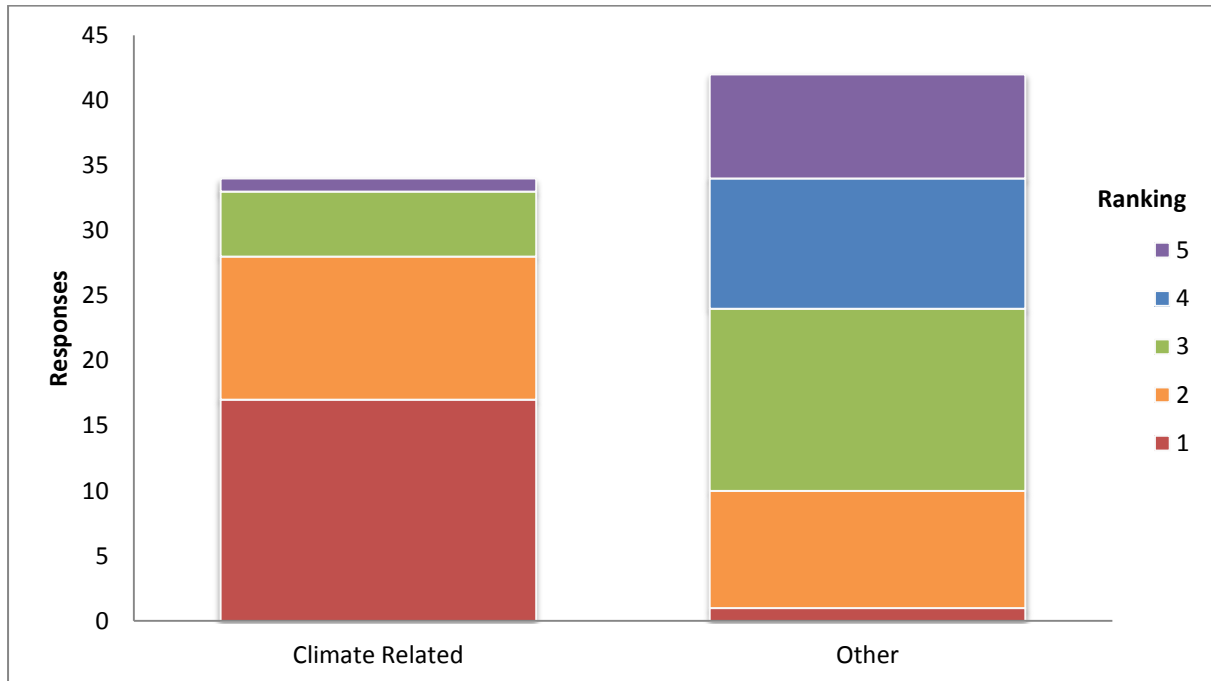


Figure 5.2 – Compiled Ranked Risks

Gaining an understanding of a groups' risk profile is a first step to being able to adapt to or cope with these risks (Adger 2006). Perceptions of risk are influenced by the characteristics of the risk and can depend on the magnitude of importance placed upon them by those at risk to them (Hampel 2006). Examples of characteristics which can influence the perceptions of a risk include: the understanding of the risk, ability to control or manage the risk, risk frequency and magnitude as well as the immediacy of consequences (Hampel 2006).

Increasing knowledge of how the farmers perceive the climate and weather related risks affecting them can provide insight to what forms of forecast information would most benefit them. From the results presented it appears that they are most concerned with rainfall amounts and timing, as rainfall had the most 1st and 2nd order significance ratings. Reducing their vulnerability to these uncontrollable and frequent events could be aided by different forms of forecast information which detail rainfall onset, occurrences and amounts.

5.2 The Farmers' Perceptions of Weather Experienced in Pandamatenga

As the weather and climate of Pandamatenga is a significant part of the commercial farmers' risk profile, it is not surprising that they have a good understanding and knowledge of the climate and what weather to expect. Their engagement with weather information has led to some detailed knowledge including how the movement of the ICTZ, as well as large storm and cyclone activity in the Mozambique Channel can affect rainfall over Pandamatenga through moisture movement across the interior of the continent. As established, rainfall is the primary risk concern for farmers, which has led to their increasing knowledge surrounding the development of weather conditions that promote rainfall. Part of this detailed knowledge may have been aided through the keeping of daily rainfall records on their farms as part of collaboration with the MET office in Pandamatenga, who collect these rain books from each farm to build up a detailed history dating back to when cultivation of the farms began in 1984. The Met office keeps and uses all of these records as an average usually to provide one daily rainfall figure for the whole Pandamatenga area. It means that there is a significant amount of daily historical rainfall data for research and several statistical analyses have been done on the area (Abdullahi et al. 2008; Alemaw et al. 2006; Kgathi et al. 2003). The agricultural research centre uses these studies to aid their research, however some of the farmers stated that the results of studies done on Pandamatenga are often not disseminated directly back to them.

While few of the farmers actually used the term variability, there is a definite understanding of the spatial and temporal rainfall variability that occurs over the area daily to inter-annually. Some of the farmers explained that they expected the variability especially in the early summer months before planting, though usually rainfall becomes more reliable from December through to February. One farmer who has been in the area for over a decade stated: "An abnormal season in Pandamatenga is a normal season." Another farmer stated that last season he had received 400mm while his neighbour received over 1000mm. With such a high variability of up to 500mm differences over the season spread over the area it may only rain over a few farms and not over all the farms on the plains. The farmers are very aware of just how localized the rainfall can be, claiming big storms can rain large amounts on a single farm while the next farm barely receives any rain. Though this seems extreme, a similar occurrence was experienced during the research time in Pandamatenga. On a farm in the South East there was a large storm which precipitated 50mm of rain in 1 hour, while

other farms in the Southern plains received less than 20mm, and those on the middle plains received none.

Eight (42%) of the farmers were under the impression from their experiences that the seasonal rainfall pattern has been changing. They feel that there has been a general decrease in total annual rainfall amounts and that peak rainfall is shifting to later in the season, possibly by up to one month later. According to these farmers, the peak rainfall in the early 1990's occurred from November to December, with some years experiencing high rainfall of up to 1000mm or more. They argue that this has changed over the last decade and that peak rainfall now occurs later in the season around the beginning of January or even into February, with less consistent high rainfall totals over the season. This could be attributed to decadal variability.

Three (16%) other farmers countered the opinion of a changing rainfall pattern and decreasing rainfall amounts, stating that this was just part of the variability experienced over the area. It was argued that the past few years in Pandamatenga had experienced very erratic and low rainfall amounts and that this was on the minds of the other farmers. One farmer, who had been in Pandamatenga since the late 1980s, suggested that some farmers had not been in the area for enough time to fully understand the weather and climate. He said that often there are several bad (low annual rainfall) years, followed by good, and that this was part of the climate cycle.

Interestingly as mentioned in chapter 3 statistical rainfall analyses done in Botswana show that there is a small, but significant and consistent decreasing trend of annual rainfall amounts over the whole country associated with a decrease in the number of rain days (Batisani 2011; Batisani & Yarnal 2010). These studies show no real changes in seasonal dispersal of rainfall, only that the peripheral summer months outside of the months of December through to February have experienced the most rainfall decreases and variability increases. With regards to the assertion that there may be several drier years followed by wet years, a study of rainfall variation specific to Pandamatenga found that "there is nothing in the data to point out that dry or wet years come in a sequence" (Abdullahi et al. 2008, 352).

5.3 Importance of Climate prediction to Farmers

A first step in the study was to ascertain whether the farmers feel the need to use forecasting information. The two sections above show that they understand their vulnerability to weather and climate fluctuations in the area. There is acceptance that forecasting has the potential to aid adaptation to climatic variations by being decision relevant (Jones et al. 2000; Stern & Easterling (eds.) 1999; Hansen 2002; Usman et al. 2005). It has been realized that for this potential to be met there is a necessity for certain conditions to be present (Lybbert et al. 2007; Usman et al. 2005). These conditions include the prerequisites for use outlined in the framework in section 2.7 as well as forecasts meeting the demands of users (Usman et al. 2005). If these conditions are not present and the user cannot use the forecast, often decisions are made more upon the understanding that users have of the general climate pattern for their region (Stern & Easterling (eds.) 1999; Jones et al. 2000).

One of the first questions in the survey asked the farmers whether the climate has a large effect on their farm planning decisions, and to answer with a simple yes or no. Only 1 of the 19 farmers interviewed stated that the climate did not have a large effect, but would not elaborate on why this was so. He merely stated that there were other more important factors, not mentioning what these factors were. It is important to realize that any risk management will depend upon the needs and factors affecting each individual user (Dilley 2000). That the majority (95%) of the farmers recognize that the climate has a large effect on their planning decisions is confirmation that they have a level of understanding of their vulnerability to it.

Identifying the types of information that the farmers find important to use in their planning is summarized in Table 5.1 below. Weather and seasonal forecasts were the most mentioned and received the highest rating of importance amongst the farmers for aiding their planning decisions. The majority of farmers stated that weather forecasts are moderately to greatly important for planning farm decisions, with only one farmer in the survey stating that they were in no way important. The seasonal and weather forecasts are ranked very similarly, with the weather forecast considered marginally more important overall. While their own weather recordings and historical data received multiple mentions, these were found to be of much less importance than the forecasts. It is logical for forecasted rather than prior recorded information to be ranked on a higher

importance level, as forecasts provide the ability to make anticipatory rather than reactive actions to cope with adverse weather and climate conditions (Hansen 2002).

	Responses (n=19)	Greatly	Moderately	Slightly	Not at all
Weather Forecasts	19	8	9	1	1
Seasonal Climate Forecast	18	7	8	2	1
Own weather recordings	13	2	6	4	1
Historical rainfall/temperature records	13	2	3	6	2
GIS maps showing climatic variables	8	0	5	2	1

Table 5.1 - Rated Importance of Forms of Information

These past three sections show how climate information could be useful in aiding the farmers, and more importantly that the farmers recognize the importance of this information. The farmers are well acquainted with their risk profile, understanding that most of their climate related risks are due to the variability of rainfall over Pandamatenga. They recognize that forecasts, rather than past data, could provide them with insight into current and future planning against the weather and climate risks they face.

5.4 Access to Climate Prediction Information

This section presents the sources that the farmers use when accessing forecast information. There are three types of forecast information presented: weekly forecasts; seasonal forecasts; and long term climate change projections. Weather and seasonal forecasts are presented and discussed

together while long term climate change projections are considered separately due to differing reactions and responses to this type of information, as discussed in the literature review chapter 2.

5.4.1 Sources of Weather and Seasonal Forecasts

There a number of different sources that the farmers use to access weather forecasts. Figure 5.3 (below) displays in percentages the number of farmers that access weather forecasts through each source. The survey allowed for and encouraged the selection of every source that the farmers use; this resulted in some farmers selecting multiple sources.

Internet (44%) and television (39%) are the dominant sources used by farmers to access weather forecasts. The television forecast is delivered by BTV (Botswana Television), as no other station provides forecasts on Northern Botswana. Several Internet sites were used, but www.yr.no was the dominant site mentioned by eleven of the sixteen farmers who use the Internet to source weekly forecasts. This site gained prominence as it provides forecasts specific to Pandamatenga in 6 hour slots for up to a week, while most other websites do not provide a weather forecast for Pandamatenga, but do for Kasane, a larger town 100km to the North. The www.yr.no website was originally discovered by one farmer who spread the knowledge of it by word of mouth to the other farmers.

Figure 5.3 shows that 8% of farmers use the Meteorological Office (MET) in Pandamatenga as a source for weather forecasts. These forecasts are disseminated through E-mail and mobile phone SMS mainly as warnings for extreme weather and can be an irregular service. Though these are not overly detailed forecasts, displaying basic temperature and rainfall predictions for Pandamatenga village for a week period, they are relevant for a short time period and very specific to the region. The interview with the Director of the Pandamatenga MET office revealed that these forecasts are sent to the majority of farmers, all whom have asked to be contacted. The inconsistent dissemination of these forecasts may have resulted in some farmers not acknowledging the MET as a source in the survey as it is not accessible at will. The MET office claimed that these emails and SMSs were delivered regularly though, and asserted that poor Internet and phone signal might disrupt their delivery (see section 5.5).

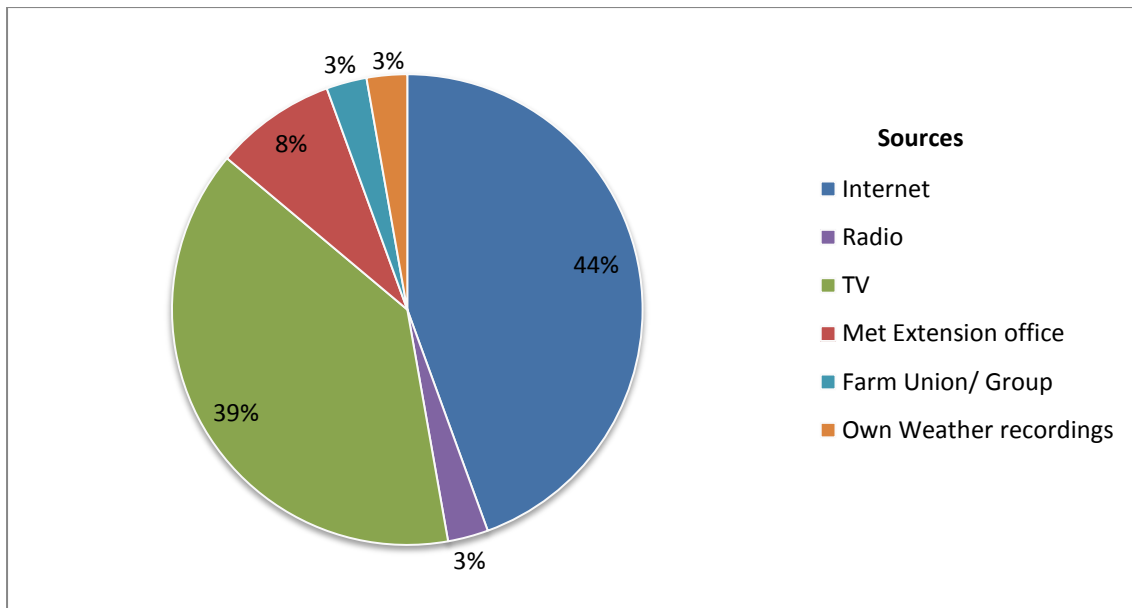


Figure 5.3 - Sources Used to Access Weather Forecasts

One farmer mentioned receiving weather forecasts from the Farm Union/Group. When questioned about it during the interview he stated that he did not have access to internet, and would rarely watch his TV, so when he wanted specific weather information he would call his colleague in the farming community to provide these details. His colleague accesses the Internet, TV and the MET office sources. So though this farmer does not have the same direct source for forecasts, he indirectly receives the same information.

The one farmer who selected that he uses his own weather recordings completed his survey without supervision and reasons for this selection could not be attained during the research time. Using his own weather recordings would only enable guesswork at an actual weather forecast. It is more plausible that this farmer did not completely understand the question in the survey with regards to sources of weather forecasts. This is important as it shows insight into not understanding the information contained within the seasonal forecast.

Figure 5.4 shows the percentage of farmers that use each source to access seasonal forecasts according to the survey results. Again farmers were encouraged to select multiple sources. Further investigation into the results showed that the farmers that access a seasonal forecast all access the

seasonal forecast that the MET office produces, and the graph shows the different ways that the farmers access this MET office forecast. Similar to weather warnings the MET office in Pandamatenga emails all the farmers whose contact details they have a seasonal outlook, usually during the month of October, which is developed by the head office of the Meteorological department for the whole of Botswana. Figure 5.4 shows that only 52% of the farmers access the forecast directly from the MET office, however some of the farmers labelled the Internet as a separate source, though is still in reference to the email from the MET office. The one farmer who received the seasonal forecast from the Farm Union/Group is the same farmer who has no TV or Internet, mentioned earlier, and accesses all his forecast information from his colleague. His colleague provides him with details obtained from the MET office seasonal forecast. One farmer who selected TV as a source, later revealed he had only seen it once on TV, and could not remember which station, but that it was a few years prior to this research. Reasoning behind the 13% of farmers that selected their own weather recordings could be a lack of understanding of what a seasonal forecast is, or confusion over the survey question. Though several examples were provided and explained for clarity, unsupervised survey completion made it difficult to interrogate all responses.

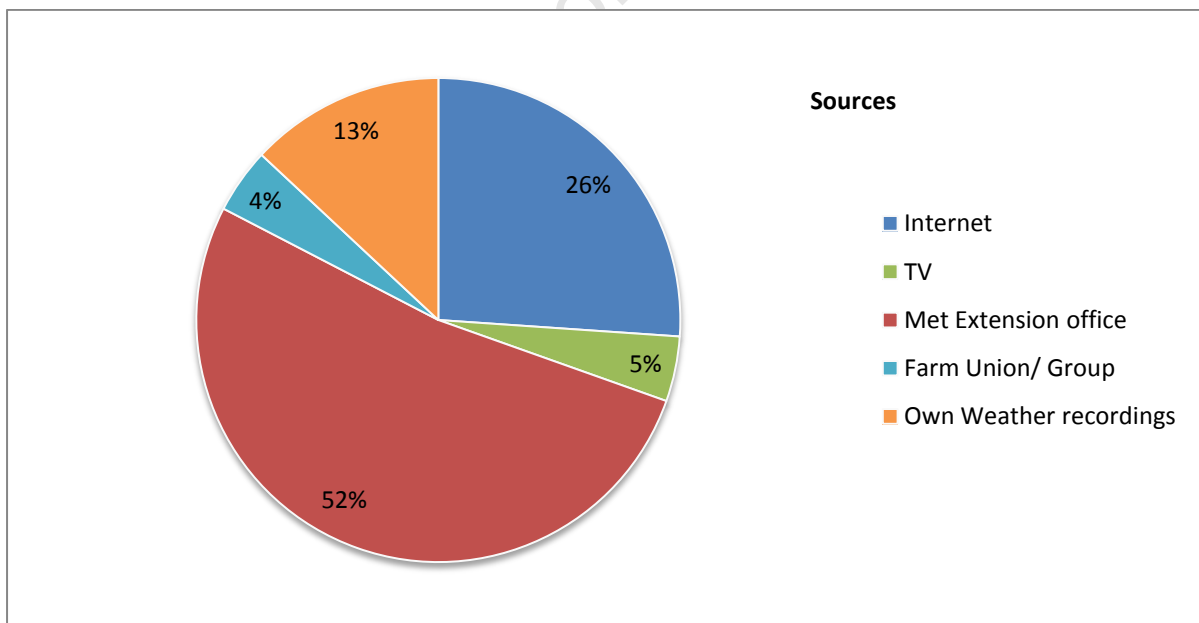


Figure 5.4 - Sources Used to Access the MET Seasonal Climate Forecast

5.4.2 Reliability of the Weather Forecasts

With many of the farmers using multiple sources for their weather forecasts, it was interesting to discover how reliable they found these sources to be in delivering consistently dependable information. The uptake of forecasts is more likely to occur when the information has a greater reliability (Roncoli et al. 2009). These results are an initial step, allowing for further interrogation of the differences between the weather forecasts received, and the farmers preferences towards forecasts depending on these differences. The responses to the reliability of different weather forecast sources are presented for comparison in Table

Reliability Level	Responses (N=19)	Good	Average	Poor
Internet (www.yr.no)	19	14 (74%)	5 (26%)	
TV (BTV)	16	7 (44%)	9 (56%)	
MET Extension Office	13	5 (38%)	8 (62%)	
Radio	1		1 (100%)	

Table 5.2 - Perceived Reliability of Weather Forecasts

As mentioned the dominant internet site accessed by the farmers is the Norwegian website www.yr.no. Interestingly it is this foreign website which is considered the most reliable source for weather forecasts rather than the Botswana based television forecast. Interrogation of this revealed that farmers could access the internet site whenever it was necessary, rather than being reliant on the prescribed time of television broadcast. This had an effect on the reliability of the forecasts as the website was regularly updated and provided more detailed weather in 6 hourly time slots, as opposed to the BTV broadcast which showed fewer weather variables for the next 24 hours.

As explained earlier, the MET office distributes its emergency information through mobile phone networks to the farmers. It is interesting that these emergency broadcasts about extreme weather events are mostly found to be of average reliability. This appeared to be the case due to the sporadic dissemination of this information, according to whenever the MET office forecasts extreme weather, which is seen by the farmers to be subjective. Occasionally large rainfall events, or very hot weather conditions can occur without messages from the MET office being received, or being received too late. For the most part the information content was considered good and accurate, but it was the inconsistent dissemination that lowered this source's overall reliability according to the farmers.

As radio was only mentioned by one farmer as being of average reliability, and that none of the farmers are actually able to receive reliable radio signal, it is regarded as insignificant.

5.4.3 Climate Change Information

The questions in the survey directed towards climate change information were structured differently from the questions concerning the weather and seasonal forecasts. The reasons behind this are associated with previous studies that have shown a limited access and use of climate change information, especially by intended users in Africa (Ziervogel & Zermoglio 2009; Maddison 2007; Patt & Schröter 2008). For this reason, climate change information questions were tailored to expect limited use amongst the farmers, and were more directed towards awareness and where access to information is gained.

The awareness of climate change amongst the farmers, as in them recognizing the existence of the term and claiming to have an understanding of what it is, was very high. Of the 19 farmers interviewed 18 (95%) claimed to have an understanding, though it was apparent that any detailed knowledge was limited. Potential impacts on their region and local area were of interest to the farmers, but were not well known to them. The most common impacts of climate change the farmers anticipate include possible seasonal rainfall changes, including increased variability and an increasing number of dry spells as a result of less rainfall and hotter temperatures. Often the farmers did not use these specific terminologies so these answers were deduced from the varied responses. With these potential impacts in mind, 84% of the farmers believe that Pandamatenga has already

begun to feel the effects of climate change, mainly from the large variability in rainfall, which many believe to be increasing.

Figure 5.5 shows the sources that the farmers access information on climate change from. Each of the bars on the graph displays the number of interviewed farmers who use that source to access climate change information; farmers were again encouraged to select multiple sources. The bars are also divided into a relative ranking that the farmers gave each source based on how good the source is subjectively perceived to be at delivering reliable climate change information. As the rankings of the sources are according to the perceptions of the farmers they are not necessarily an accurate assessment of the information contained within these sources. It was clear that their awareness of climate change did not stem from interaction with model output or from formal education on the subject. Only 32% of farmers had seen climate model outputs, and as shown in figure 5.5 below, only 3 (16%) farmers have had any formal education linked to climate change.

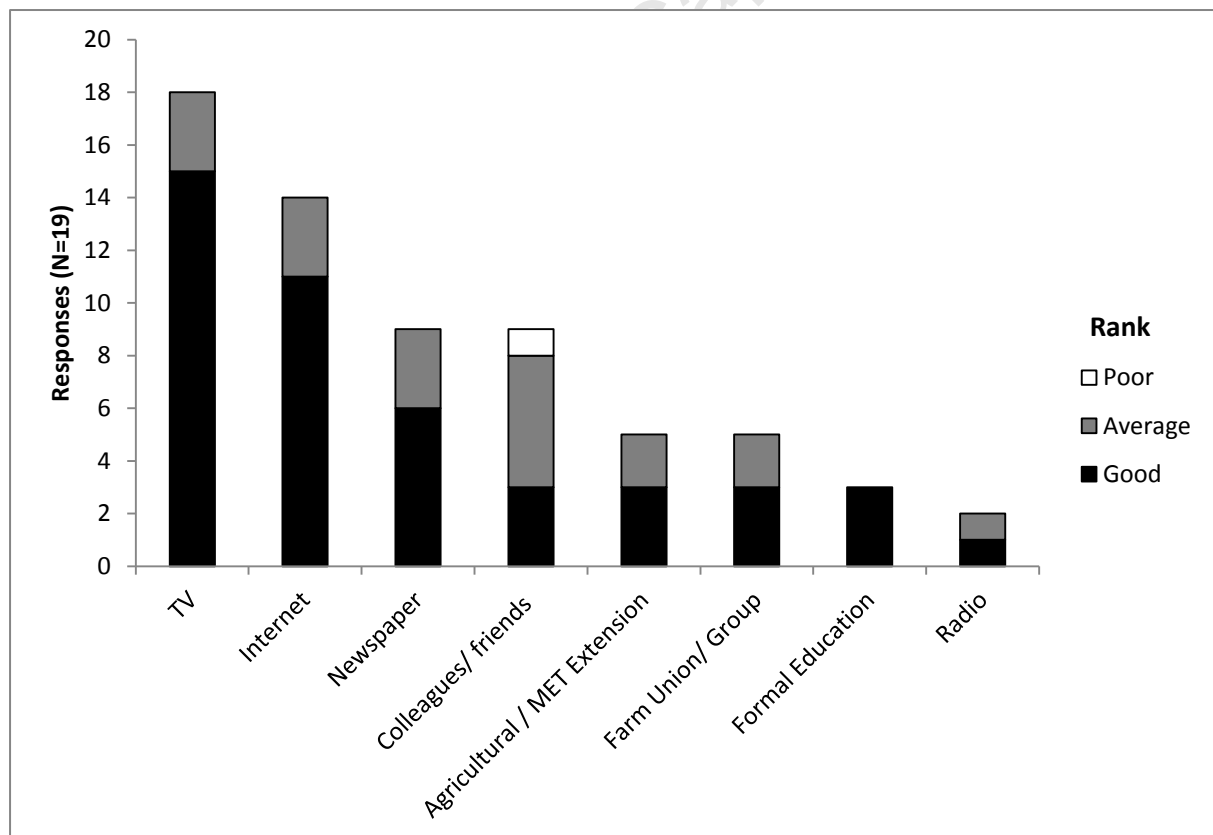


Figure 5.5 - The Sources of Climate Change Information Ranked by the Farmers

Similar to weather and seasonal forecast sources, the TV and the Internet dominate the sources where farmers access information on climate change, as they received the most mentions and highest ranking from the farmers. Information accessed from television is mainly from News channels or documentaries. No farmer was able to mention a specific Internet website where they accessed climate change information from, but 26% of them believed it was from certain News websites that ran feature climate change articles. 63% of farmers accessed information from other media sources, such as newspaper and radio but they considered these sources as less informative as only random topical stories were covered by these media. Interrogation of the responses revealed that the information exchanged through the sources of colleagues, Farm Union and the Extension services are from general discussions over information that was seen on the Internet or TV. Therefore these 3 sources could be linked together to show that several (47%) farmers do talk about climate change, but do not find exchange of the information with colleagues or others in Pandamatenga to be of particular significance.

All farmers wanted more information on climate change impacts in order to plan some adaptation strategies, dependent on what the information reported. Use of this information would depend on the potential impacts, but all claimed that if it proved relevant that they would incorporate it into planning. In the survey 89% of farmers mentioned that climate change is important to be aware of, and only 11% regarded it as not important as they were unconvinced by conflicting arguments they had heard through their information sources. Though the farmers desired more information on climate change, it became apparent from discussions after survey completion that very few (<20%) of the farmers actively seek climate change information. Rather it is probable that climate change information enters the farmers' knowledge sphere from it being a topical issue on the mass media which dominate the farmers' information sources. Mass media has been found to be the primary sources of climate change information for people in Africa, though the detail of the information contained in these sources may be limited (Ziervogel & Zermoglio 2009). Often mentioned by the farmers was that there is an overall lack of information relevant to them, which is specific to Southern Africa, and ideally Northern Botswana, which reduced their interest in the information.

Neither the Ministry of Agriculture official, nor the MET office official interviewed had ever seen or had knowledge of climate change information that was available for Pandamatenga, or even

Botswana. The Ministry of Agriculture official was aware of climate change research going on, but could not elaborate further.

New farming practices incorporated over the past few years by some of the farmers can be viewed as climate change adaptation strategies. These adaptation strategies are mostly designed to conserve soil moisture as a reaction to rainfall variability. Some of these adaptations are the incorporation of better soil management, specifically zero tillage farming in order to not expose under-soil to the sun, and therefore restrict evaporation. These soil moisture conservation techniques are reactionary adaptation responses, incorporated as a result of already experienced poor rainfall years, but are also in preparation for a changing climate that the farmers think will be drier and have less consistent rainfall. Anticipatory adaptation is limited by a lack of available information on future climate risks (Ziervogel & Zermoglio 2009). The possibility of incorporating genetically modified (GM) crops has been thought of by some of the farmers for better drought resistance and higher yields under stressful conditions, but the high prices and lack of research in the area has yet to prompt this action.

The shortage of relevant information of the climate change impacts expected for the region has been noted by other studies in Africa as a limiting factor in adaptation planning (Ziervogel & Zermoglio 2009; Ikeme 2003; Downing et al. 1997). This has been a result of a lack of research into potential impacts and a lack of data to aid research or input into models in southern Africa, resulting in the information on potential impacts being vague and unspecific to the various areas within the region (Ikeme 2003; Handmer et al. 2012). This has limited the amount of adaptation that has been implemented as there is a limit to the uptake of pertinent and applicable climate change information (Ziervogel & Cartwright 2011). The farmers in Pandamatenga experience these same issues and are unable to access relevant climate change information.

5.5 Barriers to Accessing Climate Prediction Information

This section explores the reasons why farmers may struggle in access climate prediction information. Examined here are issues which limit the ability of the farmers to access the weather and seasonal forecasts, summarized in figure 5.6, and climate change information summarized in figure 5.7. Both

figures are displayed as simple bar graphs measured by the amount of times each barrier was mentioned by the farmers in the survey; farmers were encouraged to select multiple barriers.

5.5.1 Barriers to Accessing Weather and Seasonal Forecasts

Looking first at figure 5.6, Internet connectivity in Pandamatenga was mentioned by 74% of the farmers, making it the leading barrier in accessing weather and seasonal forecasts. The Pandamatenga farmers get their Internet connection through mobile phones, which requires installing a mobile phone signal booster at their homesteads, as often the farmers homes are outside of the range of the signal tower in Pandamatenga village. A few farmers realized the lack of access to other forms of media (such as radio; newspapers; TV; or computers) limit their ability to constantly receive forecasts that are communicated through those formats. Similar to the Internet connectivity issue, radio and TV signals cannot reach their homes, unless by satellite. This was backed up by the interview with the Ministry of Agriculture official who stated that as some farmers don't have computers, and the location of Pandamatenga makes newspaper delivery and radio signal irregular, it is often difficult to communicate regular information to the farmers. He argued that SMS was useful as long as the farmers were not in the fields, but stated that this could add up to be an expensive method.

Not knowing where to find information was only mentioned by 16% farmers, and this is not surprising as discussed earlier with regard to how the farmers source their forecasts. Weather forecasts available on BTV and certain Internet websites specific to Pandamatenga are known to the majority (84%) of the farmers and seasonal forecasts are disseminated by email directly to 74% of them, eliminating the need to search for it. One farmer expressly requested knowledge on how to find seasonal forecasts, but he did not have a computer or a mobile phone Internet connection, making his ability to receive seasonal forecasts extremely difficult.

Power cuts were only mentioned once and would cut off the farmers completely from accessing any forecast, as they rely on electrically driven media. Power cuts though are not common and usually do not continue for a prolonged period of time. Most farmers claimed that navigating the Internet was new for them, especially via a mobile phone, but claimed that they were able to learn and adapt

rather quickly, but that using it to find other forecasts specific to their area, especially seasonal forecasts was difficult. So in this case computer literacy is not an issue, but locating other seasonal forecasts to the MET office one is difficult.

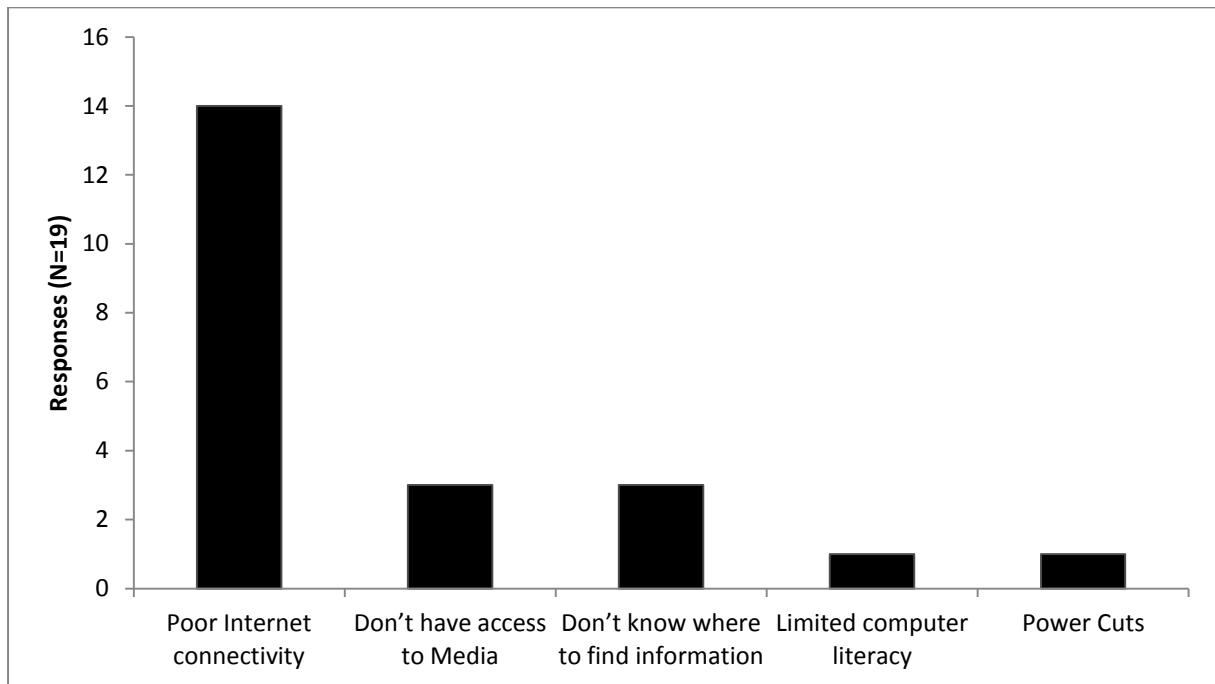


Figure 5.6 - Barriers in Accessing Weather and Seasonal Forecasts

5.5.2 Barriers to Accessing Climate Change Information

Figure 5.7 summarizes the barriers that limit the ability of farmers in accessing climate change information according to their responses in the survey. The barriers are very similar to the ones mentioned for weekly and seasonal forecasts, already discussed above. The few differences are that more (21% more) farmers admit to not knowing where to find climate change information. Many of the farmers admit that it is easy to find articles discussing climate change, especially on the Internet, but difficult to find knowledge relevant to them, as well scientifically sound knowledge that is not part of a debate over the existence of climate change. Only two farmers do not think it is necessary to access climate change information, possibly due in part to their age (elder farmers), but also as discussed above due to the lack of relevant information specific to their location and situation.

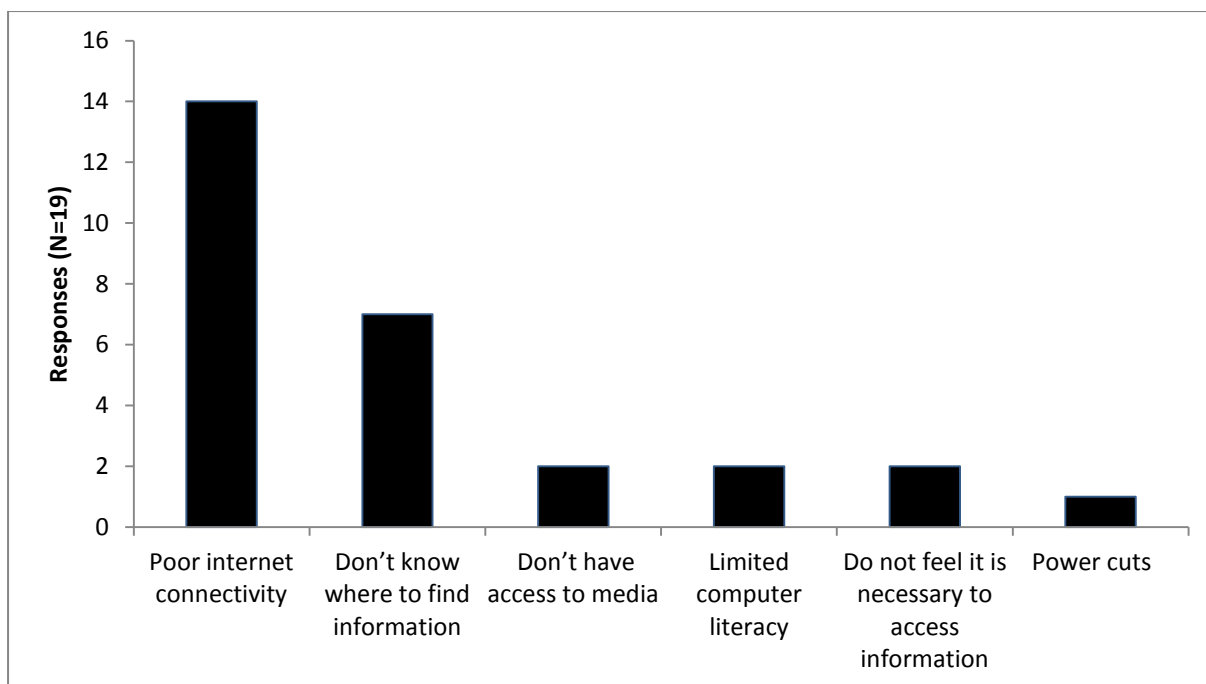


Figure 5.7 - Barriers in Accessing Climate Change Information

Most of the factors limiting access to forecasts are a result of the location of Pandamatenga, and the scale of the area which the farms span. Being a small, remote village in the north of the country it is far from any city. This limits the availability of various media formats to reach the area and requires the farmers to devise their own means of media access, such as the implementation of mobile phone signal boosters at their homesteads in order to achieve basic telecommunication and Internet communication channels.

5.6 Information and Communications Technology

Most of the sources of forecasts can be categorised as Information and Communications Technology (ICTs). The use of these technologies, especially the ability to access the internet through a mobile phone network, has expanded the potential of the farmers in Pandamatenga to access information. This is because ICTs have changed the way information and knowledge can be exchanged by a figurative compression of time and space, enabling access to information anytime and almost anywhere (Selwyn et al. 2003). The ability to make use of these ICTs, given the farmers' rural location, completely changes their interaction with information and information sources.

Ospina and Heeks (2010) outline the factors in which ICTs are able to change the interaction with information. Firstly they argue that ICTs are able to increase the asset base of people, by enabling the communication of information that would otherwise be unavailable (Ospina & Heeks 2010). This increases the information asset level of users by increasing the availability of resources, in this case the availability of different information sources. An important aspect of having multiple information sources available, opened up by ICTs, is that it enables choice (Ospina & Heeks 2010). The ability to access multiple sources means that users are able choose their preferred information source, often based on which source delivers the perceived best and most relevant information (Ospina & Heeks 2010). Lastly the use of ICTs increases the speed or timeliness of receiving information (Ospina & Heeks 2010). Information that is released on the internet or communicated by mobile phone Short Message System (SMS) can be accessed immediately.

Most (94%) of the farmers in Pandamatenga are able to access forecasts from the internet whenever they need to, and have made the choice to access the weather forecast from www.yr.no as this website provides detailed information which is perceived to be good and most relevant to their location. The possession of an email account and the ability to access it with relative ease enables the communication of the seasonal forecast to the farmers from the MET office. Those farmers without an email address or without internet access are not able to access these forecasts directly and rely on their TV for weather forecasts, which dictate the time and detail of delivery, and are unable to access a seasonal forecast.

The mobile phone is an important ICT for the farmers to possess as access to the Internet is a result of mobile phone technology and network. The mobile phone is therefore often the only means of accessing communication channels, from SMS and email to various Internet websites. The mobile phone has been found to be of particular importance in rural areas in developing countries as it often has a very high penetration (usage) rate as compared to other ICTs (Karanasios 2011). Most often used more for a means of disseminating information in disaster management early warning systems, due to widespread use and immediate timely delivery (Karanasios 2011). The MET office in Pandamatenga also uses the mobile phone as part of their early warning to farmers against extremely adverse weather conditions that may be expected.

It is important to note that the impact of ICTs, especially the ability to access the Internet via mobile networks, has enabled the farmers in Pandamatenga to access forecast sources which would otherwise be unavailable to them. In so doing the farmers' interaction with different sources and different forecasts produced has enabled them to receive more detailed and relevant information through their own inquiry.

5.7 Conclusion

This chapter has unpacked necessary elements that provide the contextual knowledge for further discussion in the following chapter. The farmers' perceptions of weather affecting them and their risk profile being dominated by weather events show that there is potential for forecast information to be beneficial. Section 5.4.1 detailed the sources of weather and seasonal forecasts used by the farmers in Pandamatenga. The weather forecasts that the farmers access are mostly obtained through active seeking, with warnings of forecasted extreme weather being disseminated through S.M.S. and email from the MET office. The most widely accessed weather forecasts are through BTV and a single Norwegian website, www.yr.no. The perception of reliability of different sources is a measure of which sources the farmers prefer to use due to the manner of delivery and information contained in the forecasts. The more detailed weather forecast in more frequent intervals was preferred by the farmers. Increased frequency was coupled with increased updating of the forecast and more detail increased the regard the farmers had for the forecast. The farmers access only one seasonal forecast which is disseminated directly to them from the MET office via email, for farmers who have opted into this free service.

As outlined in section 2.4.1 accessing forecasts is one of the main prerequisites necessary for establishing utilization of the forecasts, as of course if a forecast is unavailable, or potential users are unable to access it, then it cannot be used (Vogel & O'Brien 2003). Exploring the details of how climate prediction information is accessed by farmers in Pandamatenga helps researchers to understand their situation, and what forms of communication are successful and which are not. This chapter was a first step in analysing the prerequisites for forecast use. The other prerequisites are unpacked and discussed in the next chapter. This will include the ability to access the forecasts, and how the forecasts accessed influence the farmers' decisions and strategy planning.

Chapter 6: Results and Analysis - Use and Value

The previous chapter examined the importance of accessing forecasting information to the farmers in relation to their risk profile. This was seen as the first prerequisite for forecast use, and therefore a necessary step in determining value based on use. This chapter will further explore the relation between the farmers and the forecasts that they do access beginning by addressing the last two research objectives that formed part of the survey design that focus on the assimilation of forecast information into decision making and factors that impact the uptake and use of the forecasts.

In so doing, this chapter begins by addressing what decisions the forecasts are used for by the farmers in Pandamatenga. The subsections following this address the remaining prerequisites for use outlined in section 2.4.1: skill and quality of forecasts; confidence in the forecasts to deliver reliable and trustworthy information and; the situation of the users of a forecast including an ability to choose a different course of action. These sections are explained in relation to how the farmers use the forecasts. The chapter concludes with a descriptive analysis of the valuation of the forecasts based upon their use.

6.1 Agricultural Practice and Decisions Influenced by Forecasts

Ziervogel et al. (2010) created a decision making framework for large scale agriculture in relation to different forecast information. This framework was adapted from Schulze (2005) who created a decision making framework using different forms of climate forecast information for water resource management. The framework by Ziervogel et al. (2010) explains the types of decisions that are associated with each type of forecast. A weather forecast can be used for day to day farm decisions, termed operational decisions (Ziervogel et al. 2010). Examples of these operational decisions are field operations such as irrigation or ploughing and to cope with extreme weather conditions such as heat waves or heavy rain. Seasonal forecasts are used for medium term decisions, termed tactical decisions (Ziervogel et al. 2010). Examples of tactical decisions are related to yearly management, such as crop choice and land allocation for cultivation. Climate change scenarios are for decadal planning, termed strategic decisions (Ziervogel et al. 2010). These strategic decisions can be long term land management or large scale financial investments such as machinery, storage facilities or

drainage systems. Knowing what decisions each forecast information type can be applied to helps in applying the forecasts to appropriate situations.

Table 5.1 in the previous chapter showed that the majority of the farmers consider weather and seasonal forecasts to be moderately to greatly important in aiding the farmers with their farm management and decisions. The importance of these forecasts to specific decisions is displayed in figure 6.1 below, which shows the decisions that the forecasts influence, measured by the number of responses from the farmers. The farmers consider the weather forecast to be most influential for decisions and planning around the planting date of their crops and moderately influential for crop selection. Whereas the seasonal forecast is considered most influential in crop selection and moderately influential in their planning for a planting date. Cultivar selection and marketing are only minimally influenced by either forecast which is explained further in section 6.1.3. Cultivar selection is closely linked to crop selection and decisions around the marketing of the produce have a negligible link to the forecasts. One farmer added ploughing and spraying to the decisions influenced by weather forecasts. He stated that daily and even hourly information was very influential for these decisions as most herbicide and pesticide sprays needed to rest on the crops for a number of hours without being washed off by rain in order to be effectual. Ploughing requires an extended amount of time in the fields with heavy machinery and cannot be done during periods of high rainfall amounts or intense heat. High rainfall amounts can result in the machinery getting stuck in the muddy soils, and high temperatures will cause large amounts of evaporation resulting in abundant soil moisture loss.

The seasonal forecast influences crop and cultivar selection as they are tactical decisions that require planning several months in advance of the planting season for seed purchasing and delivery. The few responses to weather forecasts influencing crop and cultivar selection was done by those farmers that have stockpiled a supply of different crop seeds. If it gets late in the season and there has not been sufficient rain, farmers can alter their crop or cultivar selection and make a quick decision based on what weather forecasts predict towards the end of February. However the majority of the farmers do not stockpile different seeds. Seasonal forecasts are more influential as crop selection is a tactical decision that forms part of the yearly management plan, rather than a day to day operational decision.

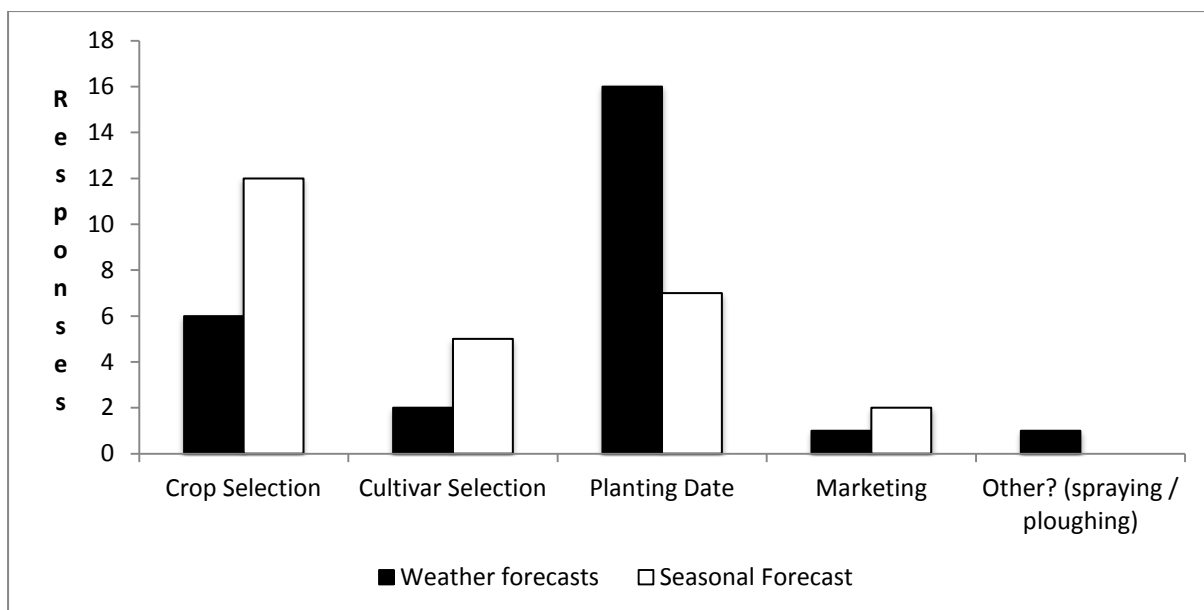


Figure 6.1 - Decisions Influenced by Weather and Seasonal Forecasts

The weather forecast is mostly used in deciding on the planting date as it relies heavily on rainfall amounts to provide sufficient soil moisture. As explained in detail in chapter 3, sufficient moisture content occurs during peak rainfall months of December through to February. Large scale rainfall events usually commence around December allowing early planting to occur from then if enough moisture has accumulated, while planting any later than February increases the risk of the crop not reaching maturity for harvest before potential winter frost events. Hence weather forecasts become increasingly influential around planting time in order to ensure planting as soon as there is enough soil moisture. Likewise weather forecasts are monitored to prepare for extreme heavy rainfall events. Too much rain and the farmers are unable to access their fields as the tractors get stuck in heavy mud, or already planted crops may be lost due to field flooding. So conditions for planting need to be ideal, and operational planning for this date is highly determined by rainfall amounts.

Seasonal forecasts are used to plan for the planting date to a lesser degree, but can be important. Though the farmers are unable to plan the exact date to start planting, further dialogue revealed that with a seasonal forecast they feel they are able to anticipate an early or late season plant, based on the crops they have chosen and the forecast's prediction on early rains. However this is a misinterpretation on their part of the seasonal forecast, as the forecast does not give any indication of rainfall onset. Nor is the seasonal forecast they receive from the Botswana MET office done on a

monthly basis, to allow separating the rainfall expected in December, January and February. The forecast is simply a probabilistic forecast of the average aggregate rainfall over all three months together. This is unpacked further later in this chapter in section 6.1.1.

37% of the farmers did not find the seasonal forecast to be of much use, even for aiding crop and cultivar selection (74% for cultivar selection). It was argued that their past experience and knowledge of the general climate and soils of the area predetermine the crops that are suitable for the area. The influence of the Botswana Agricultural Marketing Board (BAMB) in contracting the farmers to grow specific crops, and purchasing produce at previously confirmed rates also determined crop choice for some farmers. These and other factors that decrease the influence and use of the forecasts are covered in the next few subsections that analyse whether the forecasts are able to meet the prerequisites for use as outlined in the framework from section 2.4.1.

6.1.1 Perceived Quality of Forecasts

The farmers stated that most of their issues with the forecasts were to do with delivering reliable accurate predictions. This is important as the perceived accuracy of forecasts can be very influential on whether they are used or not (Orlove et al. 2004). The accuracy issues are more complicated than the forecasts not matching observed conditions, and are specific to each forecast. The main constraints to the quality of forecasts that emerged include the representation of spatial scale including the ability to predict on the local scale and confusion over the probabilistic nature of the seasonal forecast. Spatial scale can be difficult to satisfy, as the farmers desired very high resolution predictions especially from the weather forecast.

With regards to the weather forecasts, the farmers expressed the inability of the forecast to predict the spatial variability that could occur over the large farming area as an accuracy issue. Often this is a result of the type of rainfall, occurring in isolated thunderstorms. These storms may only produce rain over a few farms at a time and not the whole area, so while the forecast accurately predicted rain for Pandamatenga, the overall amount and distribution is not able to be given on a per farm scale. The 34% of farmers that didn't find the seasonal forecast influential expressed that if this potentially large disparity in rainfall distribution could be incorporated into a weather forecast over

the area, then the use of these forecasts would significantly increase. One farmer commented in his interview that “last year for example I had 400mm of rain whereas another farmer had more than 1000mm”. These large thunderstorms are accurately predicted to occur over the area by the forecasts, but cannot be predicted to specific point locations. This is not an issue over accuracy, but rather spatial scale and an inability of forecasts to predict where each rain storm will occur; an impossibility with current forecasting methods and capabilities.

The spatial concern is one of the foremost issues of seasonal forecasts as well. The seasonal forecast from the MET office is given as an image of the whole country while the farmers would prefer detailed information specific to Pandamatenga which was easier to interpret and understand. Bohn (2003) argued that there was a need to find a scale which the forecast could achieve optimal benefits, meeting farmers’ desire for higher resolution without losing the main drivers of the seasonal climate due to computational constraints. Hudson and Vogel (2003) found that some farmers find it difficult to translate a countrywide forecast and apply it to their local scale decision making. Often it is necessary to provide an interpretation in conjunction with the forecast to allow for greater understanding, which the extension office in Pandamatenga does by including a written caption for Pandamatenga based on the seasonal forecast. However even when including a written interpretation there is still a limited amount of information available in seasonal forecasts that can be applied to a specific location (see figure 3.3 for clarity).

The farmers appear to not completely understand the probabilistic nature of seasonal forecasts, and though they did not explicitly state this, it was inferred from discussions over their emphasis of accuracy issues. Seasonal forecasts often (and in the MET office case) give three probabilities, of the likelihood below, above and near normal conditions, mainly for rainfall and maybe temperature variables. In this sense the forecast can never actually be inaccurate, as any actual outcome of the variables will conform to one of the probabilities (Blench 2003; Johnston 2008). Blench (2003) explores the relationship between the scientific evaluations of probability and farmers’ perceptions of validity or accuracy of seasonal forecasts. Explaining that seasonal forecasts can be technically correct due to the nature of probability but difficult to use as an aid in decision making and may even be misleading if it encourages inappropriate actions (Blench 2003). It should also be noted that in many instances seasonal forecasts are not validated, as is the case with the Botswana MET office forecast (Blench 2003; Johnston 2008). The farmers understood the difficulty in producing a

seasonal forecast, but 5 of them claimed that its usefulness was hampered by the lack of more useful information than simply potential rainfall aggregate amounts. Seasonal forecasts do not include rainfall amounts, intensity of events, or onset and cessation. Dates for rainfall onset and temperature extremes were identified as information that could prove invaluable to long term planning by the farmers. Three farmers admitted that the MET office had conducted an education seminar on their seasonal forecast several years earlier to increase the farmers' understanding and that at the time this had been very helpful. This seminar does not appear to have been effective due to the persistent issues over understanding detailed above. The limited cognition of forecasts and the information contained within them limits the ability of the farmers to use this information (Patt & Gwata 2002).

Lead time of the seasonal forecast was considered by the farmers to be a minimal issue. The MET office seasonal forecast is released in October which the farmers find useful, as a long lead time improves their planning ability, but they think that a good deal of change can occur over the months in-between forecast release and three months that are forecasted. With the seasonal forecast for December, January and February being released in early October, there is a 5 month time gap between forecast release and the last month forecasted (February), without any updates being released. The MET office interview revealed that they attempted to release more than one forecast; one for October, November and December; and one for December, January and February. However no farmer admitted to receiving more than just the December, January and February seasonal forecast.

Climate change information that the farmers are able to access are severely lacking in relevancy and so are not salient, a necessary prerequisite for basing decisions on information (Meinke et al. 2006; Cash et al. 2002). The lack of relevancy is due to almost none of the farmers accessing detailed climate change information about Botswana or even southern Africa. This lack of any comprehensive climate change information that includes specifics on the impacts expected to be felt over Botswana or southern Africa directly limits the farmers' ability to take any action. Only 6 farmers had ever seen model outputs, with only 4 of those being specific to Southern Africa and of these 6, only 3 trusted the model output. The non-use of climate change information by the farmers is directly linked to the poor quality and lack of any relevant information they are able to access. Ziervogel and Zermoglio (2009) found that there are very few adaptation practitioners in Africa that are able to access

climate change information and those that could access the information often perceived it to be of little relevance to their location and needs.

6.1.2 Confidence and Reliability of the Forecasts

The farmers were asked to scale their level of trust placed in the forecasts they receive, recorded in table 6.1. This was done as trust or confidence in the forecasts is labelled as a prerequisite for forecast use and an important factor for achieving persistent use (Hammer et al. 2001; Lybbert et al. 2007). Weather forecasts were trusted more than the seasonal forecasts. It was found that confidence in the weather forecasts was mainly at a moderate level (89%) due to the differences in weather, especially rainfall that could occur across the farming area, again as part of the spatial variability experienced. The 89% of the farmers acknowledged that this did not necessarily mean that a weather forecast was inaccurate, but did mean that complete trust could not be placed in a forecast. These differences over the course of a season come about through a culmination of variable single rainfall events. Very little can be done to improve the confidence in the weather forecast as current forecasting abilities cannot cater for micro-scale predictions, such as specific timing of thunderstorms over specific locales.

Trust Level	Responses (N=19)	Greatly	Moderately	Slightly	Not at all
Weather forecast	19	2 (11%)	17 (89%)		
Seasonal forecast	18		10 (56%)	8 (44%)	

Table 6.1 - Level of Trust in Forecasts

Confidence in the seasonal forecast is only at the slight (44%) to moderate (56%) level due to perceived inaccuracy by the farmers. Hudson and Vogel (2003) explain that trust is closely related to the quality of a forecast and this is pertinent among the Pandamatenga. The perceived inaccuracy of the MET seasonal forecast stems from the farmers' perceived lack of quality in the forecast including its style and uncertainty over the spatial and temporal scale. Issues on the style or layout of the

forecast included the large scale areas forecasted (whole country) and general poor aesthetics which made it appear unprofessional. As discussed in the previous section the farmers found it difficult to interpret the accuracy over their area from the country scale forecast and that having a three month probability forecast was too broad to trust as it allowed for a large margin of error given the expected variability. There were 2 comments that the lead time from forecast release to months it forecasted is too long and allows for too much change in the climatic conditions which would require an updated forecast. It is interesting to note that the MET officer interviewed admitted that she was greatly confident in the quality of the weather forecasts produced by the MET service, but only moderately confident of the seasonal forecasts produced.

Luseno et al. (2003) argue that it is sometimes necessary for a forecast to change the mind-set of the user into expecting different climatic conditions from what they expect in order for confidence to be gained. It is possible that the scale of variability experienced over Pandamatenga has led to the seasonal forecast not being able to change the mind-set of the farmers away from the broad sphere of possible climatic conditions that they know are possible to occur over the three month rain season. Hudson and Vogel (2003) note that often large scale farmers tend to desire long term information but do not trust in its accuracy enough to allow it to influence or make changes to their farming practices. Rather they want seasonal forecasts as a supplement to their area and climate knowledge, their overall farming experience and other decision determining factors (Hudson & Vogel 2003; Johnston 2008). This is discussed further in the next section.

Blench (2003) argues that the dissemination of a seasonal forecast needs to be coupled with some form of support or training in order to ensure proper understanding of the forecasts. If dissemination is not coupled with training or education it will be difficult to improve the trust and confidence in the forecast as it could be continually dismissed due to its perceived inaccuracies. It could also lead to a breakdown in communication and trust between the farmers and the extension services available to them (Blench 2003).

6.1.3 Situation of the farmers

The complex nature of the agricultural system is an important factor in the uptake of forecast information as different populations can differ greatly in their use of information (Orlove et al. 2004). It should be noted that often the situation of the farmers and the factors that influence forecast uptake are out of the control of the creators of the forecasts (Murphy 1993; Jones et al. 2000). The situation of the farmers in Pandamatenga, like most agricultural communities, contains multiple factors that influence decisions and planning. It is important to note that a forecast must be incorporated into the complexity of a farming system, which includes multiple variables that are taken into account when planning and decision making (Jones et al. 2000; Meinke et al. 2000). Some of these generic factors include market conditions, climate, water, land availability, location and financial constraints (Klopper & Bartman 2003; Phillips 2003).

It should be recognised that certain actions cannot realistically be altered greatly as they are well established and fit into a farming system that already operates efficiently. This appears to be the case for a number of factors in Pandamatenga as many of the potential planning decisions are well established already. In this sense there is a lack of options available for which forecasts can have an influence in deciding upon as most of the decisions that farmers make have little flexibility.

With regards to the marketing of their crops, the farmers in Pandamatenga often do not need to take too many steps in order to sell their produce. At least 89% of the farmers are contracted directly to the Botswana Marketing Board (BAMB) for sorghum and other crops, which contracts farmers to grow certain crops, and purchases the produce of these crops immediately after harvest at a price set before the season (Khukhutha 2012). If the price set before the season turns out to be lower than the world market price BAMB increases their pay-out to farmers to meet market price (Khukhutha 2012). This means that the farmers are always able to sell the crops that BAMB purchase at minimum market value or more. BAMB purchases the majority of the crops that are grown in Pandamatenga, with a glaring exception being sunflower which 84% of the farmers plant. Sunflower can be a very lucrative crop and is sold directly from the farmers to mills, mainly in South Africa (Khukhutha 2012). Occasionally if the market price is not high enough the farmers store their produce in sturdy plastic sleeves, which are weather resistant and can be stored for several years safely (Khukhutha 2012). This is an extreme measure though and is not often conducted on a large

scale as it is highly labour intensive and means a lack of immediate capital available until the produce is finally sold. Secure storage and the immediate purchasing of the crop by BAMB means that the marketing situation in Pandamatenga is not greatly affected by climatic or weather conditions, providing the harvest was completed successfully.

Crop	BAMB Contracts	Responses (N=19)
Sorghum	Yes	17 (89%)
Sunflower	No	16 (84%)
Legumes	Yes	10 (53%)
Millet	No	3 (16%)
Maize	Yes	2 (11%)

Table 6.2 - Crops Grown in Pandamatenga and whether they are Contracted by BAMB

As at least 89% of the farmers are contracted to BAMB, their choice of crops is also predetermined to a degree, as they need to grow the crops they are contracted to sell. These crops are not chosen randomly though, they are chosen for their suitability to the area, mainly based on their proven ability to grow in the current climate. A significant shift in the climate regime would be required for these crops, for example sorghum, to lose their suitability to the climate. The influence of the seasonal forecasts over crop choice as shown by figure 6.1 above is limited to assisting decisions around crops that are already established in the area. Interviews revealed that 63% of the farmers would maintain crop preferences from year to year but may change the amount of land allocated to each crop, if multiple cropping was practiced, based on anticipated rainfall amounts.

An initial look assumes that planning around the planting dates for Pandamatenga appears to have the most potential to be influenced by forecasts, both weather and seasonal. It is the event that farmers are most concerned with planning towards and, as shown above in figure 6.1, is the decision for which the forecasts have the most influence over. However the forecasts are still not entirely effectual for this decision. The seasonal forecasts received by the farmers provide probabilities of rainfall averages over three months from December to February, not rainfall onset or even a monthly breakdown. Without this information it is difficult and dangerous to rely on it too much for preparation on an early or late planting date. Weather forecasts have proved more useful to planting date decisions in other studies (Johnston 2008; Blench 2003). This is because planting is an

action that occurs post a weather event, once sufficient rainfall has occurred such that soil moisture content can be considered adequate for germination and growth to occur. So the reality is that the planting date is determined by weather and soil moisture. Weather forecasts allow the farmers to predict a specific date for planting as they communicate reliable rainfall prediction amounts. As discussed in the previous chapter, the spatial and temporal variability of rainfall around Pandamatenga makes it impossible for the farmers to be absolutely certain of rainfall over their fields though, and so while they can prepare for planting, the actual timing is not dependent on forecasted information but rather actual weather incidents.

It has been established in other studies that the majority of farmers rely on prior knowledge and their experience to make the majority of their planning throughout the year (Johnston 2008; Blench 2003; Hudson & Vogel 2003; Lybbert et al. 2007; Patt & Gwata 2002). 53% of the farmers interviewed have more than 10 years experience farming in Pandamatenga, with a 2 (11%) of the farmers with less experience being related (sons) to the older farmers. Their experience provides them with the knowledge to maintain well-established and effective farming strategies. It is difficult to add forecasts that do not possess strong confidence levels to decision making methods that have proven effective over a prolonged period of time.

6.2 Cognition and Decision Making

This section addresses the possible decision making mentality of the farmers, and whether it is conceivable to add forecasts to their decision making or not. There is a need to understand the context and process that farmers make decisions in order to understand incorporation of the forecast or not (Roncoli 2006). In order for forecasts, or new information, to be included into decision making, there should be motivation or a need to act to change the current context for accountable benefits (Frank et al. 2011). There needs to be something wrong or inefficient that can be changed by incorporation of information that can aid the adaptation or action process.

Blench (2003) argues that the uptake of seasonal forecasts into planning decisions is often difficult for large scale farmers as compared to small scale farmers. This is because larger farms find it difficult to adjust their strategy to be more dynamic to be able to cater for external impacts such as

adverse weather. He argues that decisions and planning on large scale farms are more deterministic of the needs and requirements of the farm operations (Blench 2003). Large scale farms will purchase seeds well in advance of the season, plan for labour intake and machinery use over a certain time period, and need to plant within that period. After planting Blench (2003) argues that the remainder of the season follows a single linear strategy which does not alter much due to the prescriptive needs of the crop once planted. This does fit the Pandamatenga scenario, though the farmers are able to be somewhat flexible, within reason, of their planting date. It is better to wait for the rains, but they cannot afford to wait too long into the season or there is a risk of early frost before harvest.

Understanding the context of the Pandamatenga, and the interaction with the forecasts by the farmers suggests that the farmers rely on their heuristics to make decisions that are functionally rational, rather than economically rational. For details on different decision making theories refer to section 2.6. Economically rational decisions dictate that the best choice is determined by the largest possible financial value in the outcome, while functionally rational decisions argue for use of experience (heuristics) to make judgements inclusive of potentially negative financial impacts (Grothmann & Patt 2005; Suarez & Patt 2004; Nicholls 1999). There are arguments that this will lead to a risk aversion strategy or conservative approach, in order to lessen impacts of hazards, rather than capitalize upon potential benefits (Suarez & Patt 2004; Patt & Gwata 2002; Sherrick et al. 2000). The farmers' experience with risk diminishes their motivation to act with economic rationality, as the potential for large losses increases without risk aversion strategies. The risk aversion strategy incorporates the farmers past experience, historical record and their gut feelings (Johnston 2008). As discussed earlier the farmers in Pandamatenga place a high value in their experience and knowledge for decision making and planning. An example of this is waiting for actual rain occurrences before planting, rather than trusting a weather forecast that predicts sufficient rain.

It is possible that the farmers do not feel the need to change their farming strategies that have proven effective in the past. This could be linked to a lack of self-efficacy in their ability to make a considerable positive change, beyond their successful current methods. Motivation to act is linked to the perceived ability to change behaviour for a consistently increased outcome (Frank et al. 2011). Without self-efficacy the propensity of the farmers would be to rely more on known experience and risk aversion, rather than new information that addresses their risk profile (Frank et al. 2011). In order for a behavioural change on this level to be achieved, the information that addresses the risks

needs to disrupt a farmer's expectations to the point that his normal choices and strategies seem to be inadequate (Patt & Gwata 2002). The information, especially the seasonal forecast that Pandamatenga farmers' access are unlikely to be able to disrupt the farmers expectations to this degree.

It is reasonable to assert that the farmers in Pandamatenga display a preference to what has been termed as a status quo bias. So defined due to the preference for maintaining the current state of affairs, or not being inclined towards change due to comfort in the established routine (Suarez & Patt 2004; Patt & Schröter 2008). Status quo bias displays similar characteristics to the loss aversion strategy in that it is often driven by the view that losses can be greater than potential gains (Suarez & Patt 2004). In Pandamatenga the reliance on experience and minimal changes introduced over past years show that the farmers are, for the most part, comfortable in their already established methods, and, in fairness, these methods have proven successful, which has cemented their status quo bias. Changing from a mental state of status quo bias to one of an action bias requires the introduction of salient information that proves a new action will lead to solely positive outcomes (Patt & Schröter 2008). A difficulty in achieving this is that by definition, the status quo bias diminishes the potential for new information sources to be incorporated (Suarez & Patt 2004).

The status quo bias of the farmers towards a risk or loss aversion strategy has proven very successful to them. This is shown by maintaining planting seasons, crop choices and patience when it comes to planting decisions. Inclusion of forecasts to increase success could prove difficult, especially when the already discussed perception of the forecasts is that of inaccuracies and low confidence. Weather forecasts have shown their worth to the farmers in their inclusion in planting date preparation, but can still be occasionally unreliable, more as a result of past knowledge that spatial variability of actual rainfall occurrences can disagree with the forecasted events. The seasonal forecast has such low confidence, due to its low accuracy perception and lack of understanding, that it would be very premature to expect its inclusion into decision making, given the success of past strategies and resultant status quo bias.

6.3 Valuation of forecasts

This study has so far used a framework to assess whether the farmers in Pandamatenga meet the prerequisites for forecast use, and described how the forecasts are used to aid certain decisions. The descriptive analysis of the value of information is based upon the study of interaction between the users and the information rather than an economic analysis based on financial gains (Murphy 1993). This last section in the chapter will complete the use of the framework to address the research aim which is to assess the value of weather and climate prediction information to the Pandamatenga farmers.

The research did not delve into the consistency or create a verification scheme for quality checking the forecast information that the farmers access. We can assume that the forecasts were created with the best judgement and skill of the forecasters for their respective forecasts. The quality of the forecasts was addressed via the perceptions of the farmers rather than through a verification scheme. It has been argued that any good verification will render any forecast inaccurate and therefore reduce the quality due to the chaotic nature of the atmosphere and what forecast creators are unable to compute (Jones et al. 2000). This is especially the case for probabilistic forecasts, with Blench (2003) arguing that verification of seasonal forecasts in southern Africa being impossible due to the large spatial variability of rainfall, which would mean that even if the aggregate rainfall validated the forecast, some areas would always be characterized by extreme rainfall patterns.

The main two weather forecasts that the farmers accessed in Pandamatenga were from BTV and www.yr.no. The accessibility of these forecasts was reliant on the ownership of some form of ICT. The farmers made use of their TVs and mobile phones for an Internet connection to access these weather forecasts, which they consider to be the best they have come across so far. Both of these forecasts were seen have a good skill and quality, especially the www.yr.no forecast. This was as a result of a high perceived accuracy and large amount of detail contained within the forecast. Confidence and trust in the forecast, closely linked to the quality, was also high as the farmers realized the potential of these forecasts to aid in reducing their vulnerability and aid decision making. The operational farm decisions could become quite reliant on these forecasts and they are considered very useful on making decisions surrounding the planting date. The weather forecasts meet all the prerequisites for use and are used extensively. As a result, the value of the weather

forecasts to the farmers is high. Not being able to access or use the weather forecasts would hinder the operation of the farm as most decisions would be reactionary. Without these forecasts the preparation for a planting date would have to be limited, and no real decision could be made until after enough rain had fallen, with the hope that another storm would not flood the fields. Operations such as ploughing or spraying would have to be done without prior knowledge of rain occurrences, increasing the risk of financial loss if the rain came and washed the spray off the crops.

The seasonal forecast accessed by the farmers is mainly as a result of direct dissemination through email from the MET office in Pandamatenga to all those farmers on their mailing list, which is free and encouraged. Again to access this forecast requires an Internet connection, which does exclude some farmers who do not have such connections. The MET office seasonal forecast is perceived to be of quite low quality. Issues over the accuracy of the predictions point to a misunderstanding of the nature of probability forecasts and are compounded by the difficulty in applying regional scale information to local scale tactical decisions. The perceived low quality leads to low confidence in the forecast. Not fully understanding the forecast heightens this lack of confidence, as the forecast does not contain the desired level of information. Even if there was confidence in the seasonal forecast, the Pandamatenga farming system does not contain multiple different tactical courses which can be chosen. Crop choices are limited to those few that are suitable to the overall climate and soil type, with BAMB providing an advantageous service to contracted farmers by purchasing their agreed produce at fixed market prices. There is the potential for land management decisions to be influenced more by the seasonal forecast if the forecast could be produced as monthly predictions rather than a three month seasonal total. This might also increase the perceived quality of the forecast. Due to a low perceived quality, low confidence and few tactical choices that are influenced by the forecast, the seasonal forecast has minimal value to the farmers in its current format. Not accessing the forecast would likely not change the tactical decisions made by the farmers as they currently do not trust or understand it enough to use it to its potential.

The climate change information that the farmers access has very little value as none of them are able to use what they access for their strategic long term planning. Access is limited to generic news or documentaries, with few farmers being exposed to model outputs, only 4 having seen model projections on southern Africa, showing a lack of any real communication to deliver them climate change information. Quality and confidence of this information is negligible. This is because the

information accessed has almost no detail on impacts or relevancy to their location. There is a desire to be exposed to more climate change information as the farmers acknowledge the potential value of the information, but this would require vast improvements in detail and relevancy.

For any value to be attained from climate change information there is a need for aid to be given to farmers on accessing information that contains projected impacts that are relevant to them and their location. One of the main concerns from the farmers with regards to climate change coupled with actual climate impacts, was how much longer their current crops would be viable to be grown in Pandamatenga. There was a concern that should large changes to the climate occur over the next few decades that crop changes may be necessary. With regards to climate change information, any improvement to the quality of the information would improve its relevancy and potentially its value as the current value status is almost non-existent.

6.4 Conclusion

This chapter completed the analysis of the survey results by exploring the uptake and use of the forecast information by the farmers. The chapter began by presenting how the farmers use the weather and seasonal forecasts to assist in making specific farming decisions. The remaining prerequisites for forecast use were explored and it was found that the weather forecast met all of these, but that the seasonal forecast was limited by perceived quality, low confidence and well established farming strategies which result in a lowered uptake and use of seasonal forecasts. The chapter finishes with the descriptive valuation of the forecast information based upon their use. It was found that the weather forecast is valued highly by the farmers as it is applied regularly to assist in several decisions. Seasonal forecasts have limited value due to little direct use as it is difficult to apply regional scale information to local scale decisions and also that it struggles to meet prerequisites for use. The climate change information that the farmers access has almost no value as it cannot be applied to any decisions due to little relevancy and salience.

Chapter 7: Conclusion

7.1 Summary

The aim of the thesis was to use a descriptive approach to assess the value of weather and climate forecasts to commercial farmers in Botswana. The value was based upon the uptake and use of the different forecasts by the farmers. In order for this aim to be achieved several objectives were undertaken to assess the overall uptake and use of the forecasts by the farmers.

A survey was designed in order to meet the aims and objectives of the study, with importance placed upon the risk profile of the farmers, how the farmers access their climate information and how they assimilate and apply the climate information that they access to decisions on their farm activities. The survey was used for a selected group of farmers in Pandamatenga, Botswana. This survey and subsequent interviews with the farmers formed the bulk of the research, with two other interviews being conducted with the director of the Meteorological Centre and the Ministry of Agriculture Science officer, both in Pandamatenga.

Learned from the literature was that a descriptive value of forecasts can be achieved through an assessment of the use of the forecasts to make decisions and take action (Murphy 1993). Further interrogation revealed four consistent prerequisites that forecasts need to meet in order for them to be used. These are summarized in table 2.2 as access to forecasts, quality (skilfully created), confidence (trust in the information) and the situation of the user must allow for alternative courses of action to be available to users. The literature review concluded with the formulation of a framework in which to base the analysis of results upon. This framework was designed to illustrate whether the farmers in Pandamatenga meet the prerequisites for using weather and climate forecasts. This framework was useful and important as failure to meet these prerequisites would limit their ability to incorporate the forecasts into their decision making, which in turn would decrease the value of the forecasts to the farmers.

The results were presented and analysed in detail in chapters 5 and 6. With regards to the first objective, dealing with the risk profile of the farmers, it was found that the farmers are well aware of the risks they are vulnerable to. The risks associated with weather and climate were ranked with higher importance than other risks with special attention being paid to aspects of rainfall, including onset, total amounts and duration of rain over the summer season.

With regards to the other objectives, the key findings are presented below in diagrammatic form using the analysis framework presented in the conclusion of the literature review, chapter 2. The findings are presented in figures 7.1 and 7.2 for weather and seasonal forecasts respectively, with a short summary explanation accompanying each figure. The climate change information that the farmers accessed was found to have such limited detail and relevancy that usage of the information to aid decisions was non-existent. Awareness of climate change was high amongst the farmers, driven through mass media sources such as global news networks and documentaries, but this information is general and very few of the farmers had accessed actual model outputs, fewer still had seen outputs on southern Africa. Limited access to detailed and usable climate change information is not new and corresponds with other studies findings (Holmes & Clark 2008; Ziervogel & Cartwright 2011).

As shown in figure 7.1, the weather forecast in Pandamatenga met the prerequisites of use which leads to the forecasts having a high value with the farmers as they were used extensively for farm operational decisions. The weather forecasts were actively sought out by the farmers using the Internet and Television, making accessing the weather forecast fairly easy providing the farmer owned these forms of ICTs. The usefulness of the weather forecast was achieved because they were perceived to have good quality and accuracy for the Pandamatenga area. Regular updates, detailed information over a fine temporal and spatial scale contributed to the perceived quality of information. Perceived good quality led to high confidence in the forecast, aided also by the deterministic nature of the information. The farming system in Pandamatenga meant that the weather forecast had a high applicability to short term decisions and that clear choices on courses of action could be made using the weather forecast. All of the above aids cognitive motivation to use the forecasts and results in the actual use of the forecast being high as the advantages of weather forecast use are known and understood by the farmers.

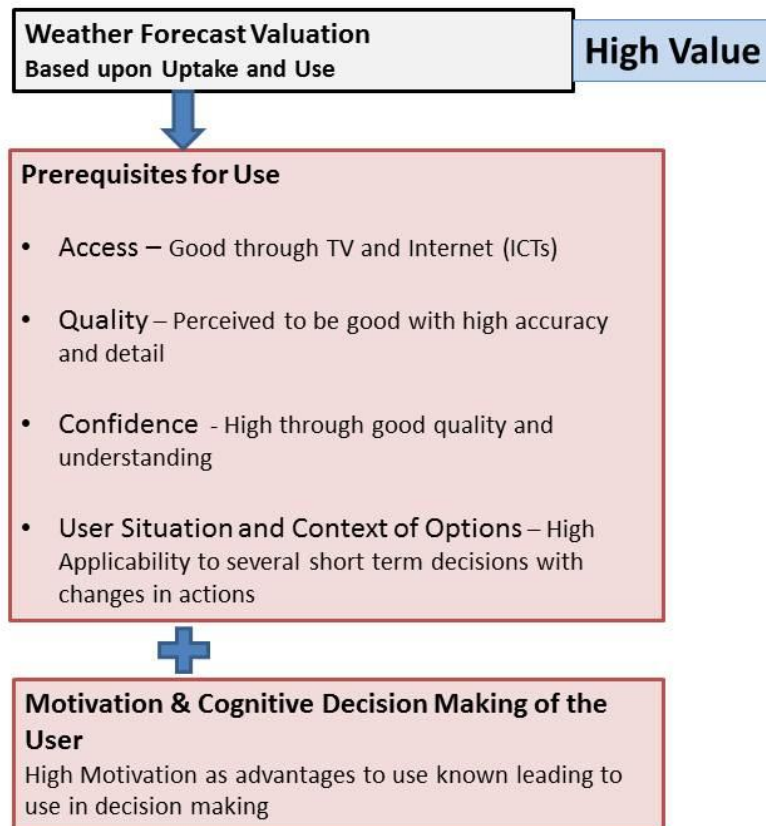


Figure 7.1 - Weather Forecast Framework Summary Findings

Though the seasonal forecast was directly disseminated to the farmers by email from the Pandamatenga MET office it was found to not be used to a large extent by the farmers. Some farmers admitted it had influence over some tactical decisions, but the majority of farmers did not apply it to decision making. Figure 7.2 shows that the seasonal forecast was constrained by a poor perceived quality and accuracy as a consequence of the coarse temporal and spatial scale it was presented in. A specific issue with the coarse resolution was the level of detailed information contained with the seasonal forecast which compounded the low perceived quality, as it was stated that probability of potential total rainfall likelihoods over a three month period was not sufficient information upon which to base decisions. Poor understanding of the probabilistic nature of the forecast became apparent throughout the interactions with the farmers, coupled with a poor perceived quality that meant that confidence in the forecast in its current form was low. The farming system had other factors (such as BAMB contracting farmers) which had large influences over the

longer term tactical farming decisions. This means that seasonal forecasts also have a lower applicability to specific decisions connecting this with the low perceived quality and confidence means that there is low motivation to use seasonal forecasts. Low motivation means there is a propensity for the farmers to adopt a cognitive status quo bias, as current farming techniques have proven effective, and seasonal forecasts are not perceived good enough to incorporate into decision making. Limited use results in the low value placed upon seasonal forecasts.

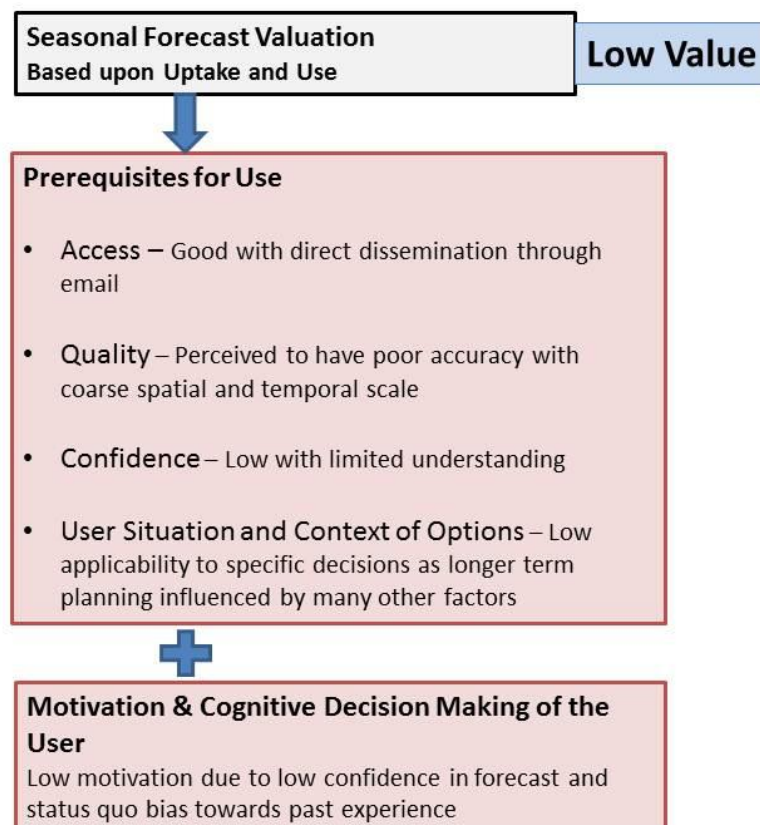


Figure 7.1 - Seasonal Forecast Framework Summary Findings

7.2 Key Findings

The analysis of the results shows that the different types of climate prediction information are received and used in different ways. Applying climate prediction information to decision making is not easy, as there are multiple different factors that influence the usability of the information,

including the content of the information, opportunities for different courses of action as well as the perceptions and cognition of the users of the information.

Seasonal forecasts have been promoted as having the potential to greatly reduce the vulnerability of people to climate impacts and climate variability (Hammer et al. 2001; McCrea et al. 2005; Usman et al. 2005). However in Pandamatenga the MET office seasonal forecast is not being used to its purported potential by the farmers. In conclusion to this study, two main findings are presented in relation to the difference between the uptake of the shorter term weather forecast and the longer term climate information, with particular attention paid to seasonal forecasts. It was found in Pandamatenga that the shorter term weather forecast had a higher uptake and use than the longer term seasonal forecast for the following two main reasons. The first finding is that uptake and use is driven by the content of the information within the forecasts. The level of detail in the information and the design as either deterministic or probabilistic influences the degree to which the user incorporates the forecast into decision making. The second finding is that the real world situation of the user can determine which forecasts are incorporated as other factors may influence choices more than the forecasts do. The following two sections discuss these two findings and their significance towards the differences in the uptake of weather forecasts as opposed to seasonal forecasts in Pandamatenga.

7.2.1 The Information Content and Perceived Accuracy of the Forecasts Drives Uptake and Use

One of the main reasons that seasonal forecasts are used less than weather forecasts by the farmers in Pandamatenga is the different perceptions on their accuracy and reliability. The accuracy of forecasts is frequently labelled as the most important factor that limits the use of seasonal forecasts (Hansen 2002; Marshall et al. 2011). The weather forecast is seen as consistently accurate and reliable whereas seasonal forecasts are perceived to be inaccurate and containing unreliable information. This study found that the design and style of the different forecasts had an effect on how their accuracy and reliability were perceived, which is important because the perceptions of the forecasts can strongly influence their ability to assist in decision making (Marshall et al. 2011). From the results of the study there are two main design factors which contribute to the perceived inaccuracy of seasonal forecasts. One is the difference in the deterministic format of the weather forecast and the probabilistic format of seasonal forecasts, and the second factor is the level of

detailed information which is included within a weather forecast, as opposed to the limited amount of information in a seasonal forecast.

As explained in detail in section 6.1.1 seasonal forecasts are probabilistic in nature, meaning that it can technically never be inaccurate as one of its predictions will always correspond to the observed conditions (Blench 2003). The perceived inaccuracy that is felt by the farmers is a result of cognitive misunderstanding of the probability forecast. This cognitive misunderstanding leads to a lack of confidence in seasonal forecasts and lowers its usability. Seasonal forecasts present a wide range of uncertainty as probabilities of rainfall are given as a percentage chance of being higher, lower or similar to the climatic mean over a three month time period. Knowledge of the climatic mean is needed to properly understand this. Interpretation may still be difficult when the differences between the percentage probabilities may be minimal, while the impacts of having above or below normal rainfall amounts over the season can be devastating to agricultural communities. This makes it very difficult for users to decide what to base tactical seasonal decisions upon. Johnston (2008) found this to be the case with South African maize farmers, in that a lack of understanding over the probability forecast, coupled with the uncertainty inherent within a seasonal forecast led to a loss in confidence and use. Patt and Gwata (2002) argue that seasonal forecasts may find more value through use in years where there is an extreme deviance from the climatological mean, such as an El Nino year, which is what they were originally designed for. The reason for this is that a skilled forecast should be able to predict this deviance from the mean with high degree of confidence, making a clear high probability towards above or below normal rainfall season. This allows for the forecast to be used with confidence by users as such high percentage probability will remove the chances of a user engaging in a best-guess scenario, often the case with lower deviances in the probabilities.

The farmers are more familiar and comfortable interacting with the weather forecast, which is of a more deterministic nature, as opposed to the probabilistic seasonal forecast. Though weather forecasts are still probabilistic with regards to potential rainfall, the information is delivered with more certainty; as in one percentage chance of rain is given (e.g. 60%) as opposed to 3 possible percentages in a seasonal forecast (below normal, normal, above normal chances). Weather forecasts are also deterministic with regards to temperature. Deterministic forecasts are much easier to understand, as they outline a clear prediction for variables over a specific location for a

particular time period. There is very little uncertainty within a deterministic forecast due to its detailed delivery of the information. Inaccuracy in the weather forecasts is minor and only stems from the potential for extreme spatial variability of rainfall over the area. Users have the ability to test the accuracy of a weather forecast on an everyday basis by daily observations, which will aid in an accurate perception of the forecast if it is produced with skill. Seasonal forecasts require detailed verification schemes which include total seasonal rainfall amounts to test the probabilities forecasted. This is not easy and requires access to historical data and a certain level of statistical skill to measure recorded amounts against climatic trends and the probabilities of the forecast.

The degree to which the farmers used the forecasts showed a strong correlation to the level of detailed information that was contained within the forecast. The perception of the weather forecast as accurate and reliable is aided by the level of detail which is included in the forecast. Inclusion of a number of variables on both a temporal and spatial scale to which the farmers are able to associate with allows them to derive information from the forecast which influences their operational decision making. The MET office seasonal forecast only displayed a three month aggregate of potential rainfall deviations from the mean. This is predominantly the level of detail that seasonal forecasts communicate (Goddard et al. 2001). Advances may have been made in the models that produce seasonal forecasts but there has been little improvement in the degree of detailed information that can be communicated with any kind of certainty (Marshall et al. 2011). Despite this lack of improvement to the level of detail in seasonal forecasts, this study, like many others, highlights the desire from users for more detail as a single probabilistic forecast of the entire season by itself is not useful (Ingram et al. 2002; Luseno et al. 2003; Roncoli et al. 2009; Usman et al. 2005).

Highlighted as an issue by the farmers was the large spatial and temporal scale that the forecast is designed to show. The perception of seasonal forecasts containing uncertain information is influenced by the coarse resolution and temporal scale of the current forecast, as the users are unable to interpret the information and apply it to their particular location for a particular activity (Johnston 2008; Marshall et al. 2011). Nadav-Greenberg et al. (2008) found that understanding uncertain information could be achieved by communicating the information through carefully designed visual representations; much like a how a seasonal forecast is produced. However they found that poor scaling of the information would diminish the ability to interpret the information leading to an amplification of the uncertainty in the perceptions of the user (Nadav-Greenberg et al.

2008). This has implications for seasonal forecasts as the coarse spatial scale diminishes the ability of the user to understand the forecast and interpret the information in order to apply it to their decision making.

Bohn (2003) argues that in order for seasonal forecasts to deliver desired detailed information for users, it is necessary to understand what type of event most concerns the users of the seasonal forecasts. For seasonal forecasts to increase in use and value there is a need for both improvements to the information as well as improved education of how to interpret the information contained in the forecast (McCrea et al. 2005). Some farmers expressed that an education programme to improve the understanding of seasonal forecasts would better their ability to interpret and use the current information. The farmers desired an increase in the detail of seasonal forecasts including predicted dates for rainfall onset, though currently seasonal forecasts are unable to predict this (Marshall et al. 2011). Increased detail could be achieved by changing the format of the forecast to show probabilities of rainfall totals on a monthly temporal scale, rather than totals for the entire three month summer season. It was also argued that updating this forecast and releasing the new results on a monthly basis from October to February would allow the farmers to be more informed on what to expect.

As the weather forecasts are used with regularity and impact the farmers on an operational level they are highly valued. It is unlikely given current forecasting capabilities that any meaningful improvements could be made to the Internet weather forecast accessed, however the BTV forecast could incorporate more detail into their weather forecasts. Increasing the detail in the MET office to the standard of the www.yr.no weather forecast would be of assistance to those without an Internet connection, and would lessen reliance on a weather forecast created outside of the country and on a poor Internet connection.

7.2.2 The Complex Situation of the User can Determine Use of Forecasts

Incorporating forecasts into a farming system that already has so many complex factors influencing its decisions can be difficult unless there is a clear correlation between using the forecasts and vulnerability reduction (Marshall et al. 2011). Seasonal forecasts are designed to address tactical

farming decisions which require long term planning, often several months. Over this amount of time it is often that due to the complex nature of the real world user situations other factors will have a greater influence over the tactical planning than a seasonal forecast. An example of this in Pandamatenga is the choice of crop types. Seasonal forecasts should be able to influence this decision by informing the farmer of an expected wetter or drier season than normal, and in so doing allow the farmer to decide on a crop type which would produce a greater yield under wet or dry conditions. However most of the farmers in Pandamatenga are contracted to BAMB that outlines which crops they will purchase. As such, there is a limited amount of choice for different crop types and the farmers are comfortable in allowing their crop choice to be determined by the marketing board in this way. Well established methods of farming are often dominant in long term decision making, which limits the uptake of new information; such as seasonal forecasts (Hudson & Vogel 2003; Johnston 2008).

It has been found that organizations with more flexible decision making frameworks are more likely to use new information (Lemos et al. 2012). But as mentioned in section 6.1.3 large scale farmers must make certain decisions at specific times over the course of a season regardless of external events, which can result in a less dynamic farm strategy (Blench 2003; Marshall et al. 2011). If the past strategies have proven successful there can be a tendency for users to ignore, or place little confidence in new information in an effort to preserve the past practices (Luseno et al. 2003). The Pandamatenga farmers have overall proven to be very successful farmers, with only occasional years or individual farming losses.

As section 7.2.1 explained, seasonal forecasts do not contain enough detailed information and is in a format that does not promote uptake and understanding of the information. As a result it is difficult for it to be incorporated into a complex system that already has several factors determining and influencing decisions over the farm strategy. The usability of the forecast is highly dependent upon the perceptions of how the information can be used by the user (Lemos et al. 2012). Without being able to see how and where to apply the forecast it is unlikely for it to be applied accordingly.

In contrast the weather forecast is applied to operational decisions, which affect specific activities in the short term. This means that the results and benefits of the weather forecast are easily and quickly realized by the farmers. Prediction of heavy rain for the next day means the farmer cannot

access his fields to spray, plough or plant. Prior detailed knowledge on the operational or day to day timescale is easily applied, as it is clear how this information affects the farm activities, requiring decisions to be made in response to the weather forecast.

7.3 Implications for the Future

With the current constraints to producing a seasonal forecast that contains the level of detail that farmers desire, a recent study by Lemos et al. (2012) argued that in order for the uptake and use of seasonal forecasts to be increased there is a need for advances in institutional dissemination of the forecast. They argued that the use of forecasts depended greatly on the perceptions of the forecast by the user, which could be altered and improved by an increase in the interaction between the producers and the potential users of the seasonal forecasts (Lemos et al. 2012). Education programmes for users of forecast information have also been recommended by other studies and were suggested by some of the farmers in this study in order to increase the understanding of the seasonal forecasts (Patt et al. 2007; Roncoli et al. 2009). However from the results of this study it is unlikely that increasing the understanding of the seasonal forecasts alone will be enough to increase its use. The applicability of seasonal forecasts are still limited by its lack of detailed information and format scale that farmers desire and this needs to be addressed by the creators of seasonal forecasts.

Focus should go into improving the spatial and temporal resolution of the seasonal forecasts. This should improve the understanding of the information contained within the forecast and would improve the perceived quality of the forecast. The perceived quality would improve through understanding and an improved ability to deduce location specific information for more specific timescales. Though this may be difficult to achieve, efforts could go into improvement of the models and the inputs of atmospheric physics with attempts at downscaling the information in order to improve the spatial resolution. A shortening of the temporal scale format of seasonal forecasts from three months to monthly could aid in decision making by increasing the certainty of each month's conditions. Though education programmes and increasing understanding of the seasonal forecasts alone may not increase their use, the worth of these initiatives should not be ignored, as an increased understanding will increase the confidence of the user when interacting with the information (Luseno et al. 2003).

Seasonal forecasts are unlikely to attain the same level of value that is afforded to a weather forecast, because of the nature of the decisions that can be influenced by each of the forecasts. The weather forecast is directed towards operational or day to day decisions, which can be directly influenced by certain weather variables, such as rainfall or high temperatures over a short time period (Ziervogel et al. 2010). This allows the weather forecast to be directly linked to a decision on whether to perform a certain activity or not, placing a great value upon it. Seasonal forecasts cannot be used for operational decisions, but rather for tactical decisions pertaining to farm strategies (Ziervogel et al. 2010). As a result it is more difficult for seasonal forecasts to be directly linked to a decision to be made pertaining to a specific activity. Rather certain strategies are influenced by the forecast, but due to the longer time period associated with these strategies, other factors, such as market conditions, will always play an influential role in driving these decisions. Seasonal forecasts can be thought of as a tool to assist tactical decision making, but is unlikely to directly determine specific actions. As a result the value of the weather forecast will always be greater than that of a seasonal forecast.

This applicability is not an issue with the forecast, but can be increased with an increase in assistance from the developers of seasonal forecasts. Advisory bulletins that give suggestions and education on how seasonal forecasts may be used could increase their value without the need to apply a seasonal forecast to a specific decision or action. This could be done by the developers of forecasts or science communicators, though it would also require a strong understanding of the situation of the user in order to provide beneficial guidance on how seasonal forecasts can be applied to user contexts.

Into the future more detailed direction could be given to the methodology to include issues such as more detail on specific use of a particular forecast. This would incorporate a more in depth analysis of cognitive decision making. This can be done as a follow on from this study, as this study details an exploratory methodology, which can be given greater direction depending on the exploratory findings. This study chose to cover all the prerequisites for use, however if more direction was given then individual prerequisites could be targeted for a more in depth analysis.

7.4 Limitations of the study

This study found that the confidence in seasonal forecasts is low, limiting its use, while confidence in the weather forecast was high which aided its use. This was found to be linked to the perceived accuracy and quality of the forecast. It has been stated that confidence and understanding of new information will increase with exposure over time (Luseno et al. 2003). For this reason it would have been useful to record how long the MET office had been disseminating their seasonal forecast to the farmers in order to discover whether the information is in fact new; however this information was not found. If a similar study was done on the area this information could also determine whether confidence and understanding of the seasonal forecast has increased or not over time.

The analysis on accessing the forecasts through different sources could have been improved if the survey had specifically asked whether the farmers owned certain ICTs such as TV and Internet. The study assumed that if the farmers possessed this media they would have used it as a source and therefore would have marked this in the survey. However it is possible to own the media and not use it for the accessing of forecasts which could mean that some farmers prefer to use certain sources to access information.

7.5 Conclusion

In conclusion this study has highlighted the difference in the use and value of forecasts at different temporal scales, mainly due to differing quality and applicability to specific farm level decisions. The study highlighted that forecasts are not useful and beneficial to farmers simply because they are created and disseminated. Access is required for use, but does not determine it. The weather forecast is used extensively due to high understanding and applicability to specific decisions. Seasonal forecasts are currently unable to greatly assist with specific farm scale decisions, and the users are unable to fully comprehend the probabilistic nature and the reasoning behind the design and format of the forecast. Climate change information is so limited in terms of relevancy and detail that use in its current form is impossible. This results in users finding it difficult to build up confidence and a positive attitude towards the longer term climate information of seasonal forecasts and climate change information.

While most valuation analyses of forecast information concentrate on the economic or financial benefits that can be gained through forecast use, this study illustrates that a detailed case study analysis can provide a descriptive valuation that is more based upon the overall uptake and use of forecasts. While concentrating on financial value can provide clear potential benefits of using forecasts, the results from this thesis suggest that currently users may not be able to employ the forecasts to their intended potential. This is especially true of the longer term climate forecasts which need to be enhanced and fully understood before their potential financial value will ever be realized. This means that although a financial valuation may prove more efficient as an assessment for potential value, this is difficult to do in a real world scenario if the forecasts themselves are not already used. As such this study, along with the framework devised, helps to expose what factors constrain the value of a forecast according to whether it is used or not.

The framework devised here is a useful and simple tool for assessing forecast readiness. Using the framework to appropriately describe certain factors that are needed in order for forecasts to be used helps to expose the strengths and weaknesses of each forecast. The necessary motivation aspect, as a result of confidence and user context, also highlights whether users are willing and able to include the information into their cognitive decision making. In this way the framework can assess both the aspects of the forecast as well as whether the users are able and willing to use the forecast, allowing the researcher to pinpoint specific issues that limit forecast use.

The low use and value of the longer term information, especially seasonal forecasts, may question whether it is still worthwhile disseminating these forecasts to farmers. It is important to realize that although there may be little overall use, the information is still desired for the sake of having more information and that familiarity fosters understanding and confidence. The potential is also there for seasonal forecasts to be more useful into the future as climate change increases seasonal deviations from the climatic norm.

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Appendix 1: Survey to Commercial Farmers in Pandamatenga, Botswana

Questionnaire No:	
Farm Location:	
Tel:	
Email:	

Demographic Data

1. Name:

2. Age:

3. Highest level of education gained:

Primary School Secondary School Bachelor's Degree Honours Degree

Master's Degree Doctorate Other Please Specify

4. How long have you farmed in Pandamatenga?

Years:

5. Where have you farmed before? List your latest locations.

.....

.....

General Questions

6. Farm Size: (in hectares)

7. Main crops on the farm:

Crops	Area (Ha)

8. Do you irrigate any area of your farm? If yes what percentage more or less.

YES NO PERCENTAGE:

9. Do you keep rainfall and temperature records on your farm? If yes for how long.

YES NO YEARS:

10. Does the climate have a large effect on your farming planning decisions?

YES NO

11. List the 5 main risks you face in your farming activities in order of importance.

1.
2.
3.
4.
5.

Current Climate information uses and requirements

12. What types of weather/climate information do you use? And where is it accessed from? (Please see examples for clarity). (Use an 'X' to show which information type you use and where you access it from).

Type of information	Internet	Newspaper	Radio	TV	Agricultural Extension Officer	Farm Union/ Group	Own Weather recordings	Other: (Please Specify)
Daily/weekly forecasts (Future)								
Long-term (3 month/Seasonal) predictions (Future)								
Own weather recordings (Past)								
Historical rainfall/temperature records (Past)								
GIS generated maps showing climatic variables (Past)								
Other: (Specify below)								

13. How would you **rank all** these information sources for delivering **reliable information**?

Source	Good	Average	Poor
Internet			
Newspaper			
Radio			
TV			
Agricultural Extension Officer			
Farm Union/ Group			
Own Weather recordings			
Other: (Please Specify)			

14. What are your **top 3 preferred** sources of climate and weather information?

- a.
- b.
- c.

15. How much weather information do you require?

Much more	More	I have Enough	Less

16. Do you think you can make a more informed decision with more information?

Yes	No	Not sure

17. Do you think it is possible to assimilate and use all the information you receive?

Yes	No	Not sure

18. To what degree do you **trust** these forms of information, based on your experiences and the examples given? **(Use an 'X')**.

	Not at all	Slightly	Moderately	Greatly
Daily/weekly forecasts (Future)				
Long-term (3 month/Seasonal) predictions (Future)				

19. Are there any natural signs that you use to predict the long-term rainfall or weather? If so, describe:

.....

.....

20. To what extent are these forms of information **important to your planning**, based on your experiences and the examples given? **(Use an 'X')**.

	Not at all	Slightly	Moderately	Greatly
Daily/weekly forecasts (Future)				
Long-term (3 month/Seasonal) predictions (Future)				
Own weather recordings (Past)				
Historical rainfall/temperature records (Past)				
GIS generated maps showing climatic variables (Past)				
Other:				

21. Which aspects of your decision making do these information sources influence? (Use an 'X').

	Crop Selection	Cultivar Selection	Planting Date	Marketing	Other?
Daily/weekly forecasts (Future)					
Long-term (3 month/Seasonal) predictions (Future)					
Own weather recordings (Past)					
Historical rainfall/temperature records (Past)					
GIS generated maps showing climatic variables (Past)					
Other:					

22. Would you find it useful to have access to both **historical rainfall and crop yield data in your area** for planning and decision making?

YES NO NOT SURE

23. Have you ever used **crop modelling** information (growth or yield forecast) to predict your crop yields?

YES NO

IF YES:

Was it helpful? YES NO

Where/who did the modelling?

24. What barriers do you experience that hinders your use of and access to weather and climate information? (Use an 'X').

Barrier	
Don't understand available information	
Don't have access to: Computer/ TV / Radio / Newspaper (Circle appropriate media)	
Don't know where to find information	
Poor internet connectivity	
Limited computer literacy	
Other: (Specify)	

Future Climate Change Information

25. Do you have an understanding of what Climate Change is?

YES NO

26. Have you seen projected climate model outputs?

YES NO

If yes: Was this specific to your region? (Southern Africa)

YES NO

Did you understand the climate model output?

YES NO

Did you trust the climate model output?

YES NO

27. Is Climate Change a factor that you consider important to be aware of?

YES NO NOT SURE

Explain:

28. Do you think we have already begun to feel the effects of climate change?

YES NO NOT SURE

29. Where does your knowledge on **climate change** come from? How would you **rank all** these information sources for delivering **reliable information on climate change**?

Source	Use	Good	Average	Poor
Internet				
Newspaper				
Radio				
TV				
Agricultural Extension Officer				
Farm Union/ Group				
Colleagues/ friends				
Formal Education (School/University)				
Other: (Please Specify)				

30. Would future climate change scenarios (specific to your region) will be of interest to you?

YES NO NOT SURE

31. Do you know of potential impacts of climate change that could affect you and your area?

YES NO

If yes please provide a few examples you know of:

.....
.....

32. Have you thought about incorporating climate change impacts into your future management actions?

YES NO

If YES have you taken any actions based on climate change impacts already? Please explain:

.....
.....
.....

33. If you had knowledge of projected climate change impacts specific to your area, would you use this information in future planning?

YES NO NOT SURE

34. Would you like to be more aware of climate change and its impacts specific to your region?

YES NO

Please explain why:

.....
.....

35. What barriers do you experience that hinders your use of and access to climate change information? (Use an 'X').

Barrier	
Don't understand available information	
Don't have access to: Computer/ TV / Radio / Newspaper (Circle appropriate media)	
Don't know where to find information	
Poor internet connectivity	
Limited computer literacy	
Do not feel it is necessary to access information	
Other: (Specify)	

Open-ended discussion questions (ask for recording)

36. What suggestions for improvements and changes, or any other comments do you have for the producers of forecasts information?

.....

37. Does the Meteorological Department (or other department) in Botswana release weather or climate warnings to you? (Such as projected drought, or storm occurrence)?

.....

38. Do you think there is enough climate information flow within Botswana to prepare you and aid your planning?

.....
.....

39. Are there any Government practices or mechanisms in place to assist farmers in coping with climate variability (e.g. drought, floods)?

.....
.....

40. What more information about climate change would you like to know or have access to in order to assist your adaptation planning?

.....
.....

41. Do you work with other Government departments or Non-governmental institutions on research and adaptation planning for climate change?

.....
.....

42. Further interrogation of survey as needed.

University of Cape Town

Appendix 2: Questionnaire Interview for Ministry of Agriculture Official in Pandamatenga (Science Officer)

Questionnaire No:	
Title (Position)	MoA Science Officer
Name:	
Tel:	
Email:	

General Questions

1. Does the Ministry keep rainfall and temperature records for the Pandamatenga area? If yes for how long.

YES NO YEARS:

Are these records freely available to farmers in the area?

YES NO

2. Does the weather and climate have a large effect on your planning decisions within the Pandamatenga area?

YES NO

Examples:

.....

.....

3. List the 5 main risks you think affects farmers in Pandamatenga order of importance.

1.
2.
3.
4.
5.

Current Climate information uses and requirements

4. Does the Ministry partner with other government agencies or non-governmental institutions to provide climate and weather data to the agricultural sector?

YES NO

5. What types of weather/climate information do you use and distribute to farmers? (Please see examples for clarity). (Use an 'X')

Type of information	Source Used	Distributed to Farmers
Daily/weekly forecasts (Future)		
Long-term (3 month/Seasonal) predictions (Future)		
Own weather recordings (Past)		
Historical rainfall/temperature records (Past)		
GIS generated maps showing climatic variables (Past)		
Other:		

6. What mechanisms do you use to distribute information to farmers? Mark if the information is weather or climate related. If it isn't related then give an example of what the information is that is distributed (e.g. market prices, diseases).

Source	Method Used	Climate / Weather info	Other info (example)
Internet			
Newspaper			
Radio			
TV			
Agricultural Extension Officer			
Farm Union/ Group			
Other:			

7. Have you ever used **crop modelling** information (growth or yield forecast) to predict crop yields?

YES NO

IF YES:

Was it helpful? YES NO

Where/who did the modelling?

Accessibility of information

8. What are **The Ministry's** weather and climate information sources? How would you **rank all** these information sources for delivering **reliable information**?

Source	Use	Good	Average	Poor
Internet				
Meteorological Centre				
TV				
Radio				
Other: (Please Specify)				

9. What is The Ministry's **preferred** source of climate and weather information?

.....

10. What barriers do you experience that hinders the Ministry's **use and access** to weather and climate information?

Barrier	
Information is difficult to interpret and understand	
Don't know where to find information	
Poor internet connectivity	
Limited computer literacy	
Other: (Specify)	

11. What barriers do you experience that hinders The Ministry’s ability to **distribute** weather and climate information? Especially to the Pandamatenga farmers.

Barrier	
Farmers Don’t understand available information	
Farmers Don’t have access to: Computers / TV / Radio / Newspaper (Circle appropriate media)	
Farmers have Poor internet connectivity	
Farmers have Limited computer literacy	
Other: (Specify)	

Future Climate Change Information

12. Do you have an understanding of what Climate Change is?

YES NO

13. Does the Ministry have access to projected climate model outputs?

YES NO

If yes: Is this specific to your region? (Southern Africa)

YES NO

Can the Ministry interpret and understand the climate model output?

YES NO

14. Is Climate Change a factor that the Ministry considers important to be aware of?

YES NO NOT SURE

Explain:

15. Do you think we have already begun to feel the effects of climate change?

YES NO NOT SURE

16. Where does the Ministry's knowledge on climate change come from? How would you rank all these information sources for delivering reliable information on climate change?

Source	Use	Good	Average	Poor
Internet				
Newspaper				
Radio				
TV				
Meteorological Centre				
Formal Education (School/University)				
Other: (Please Specify)				

17. Do you think future climate change scenarios (specific to your region) would be of interest to the farmers in Pandamatenga?

YES NO NOT SURE

18. Do you know of potential impacts of climate change that could affect Botswana?

YES NO

If yes please provide a few examples you know of:

.....
.....

19. Have you thought about incorporating climate change impacts into your future management actions?

YES NO

If YES have you made any actions based on climate change impacts already? Please explain:

.....
.....
.....

20. If you had knowledge of projected climate change impacts specific to Botswana, would you use this information in future planning?

YES NO NOT SURE

21. Would you like to be more aware of climate change and its impacts specific to your region?

YES NO

Please explain why:

.....
.....

22. What barriers does the Ministry experience that hinders the use and access to climate change information?

Barrier	
Unable to properly interpret and understand the information (model outputs)	
Don't know how to access the information	
Do not feel it is necessary to access information	
Other: (Specify)	

Open-ended discussion questions (ask for recording)

23. What suggestions for improvements and changes, or any other comments do you have for the producers of forecasts information?

.....

24. Does the Meteorological Department (or other department) in Botswana release weather or climate warnings to you? (Such as projected drought, or storm occurrence)?

.....

25. Are there any Government practices or mechanisms in place to assist farmers in coping with climate variability (e.g. drought, floods)?

.....

26. What more knowledge on climate change would you like to know or have access to in order to assist your adaptation planning?

.....
.....

27. Do you work with other Government departments or Non-governmental institutions on research and adaptation planning for climate change?

.....
.....

28. Is there a policy currently or in drafting that includes the circulation of weather and climate change information?

.....
.....

29. Does this policy promote adaptation to climate changes?

.....
.....

30. Further interrogation and interview as needed.

**Appendix 3: Questionnaire Interview for Director of Meteorological
Department, Pandamatenga Office**

Questionnaire No:	
Title (Position)	Director MET Pandamatenga Office
Name:	
Tel:	
Email:	

Current Climate information uses and requirements

1. Does the Department keep rainfall and temperature records for the Pandamatenga area? If yes for how long.

YES NO YEARS:

Are these records freely available to farmers in the area?

YES NO

2. Does the Department partner with other government agencies or non-governmental institutions to provide climate and weather data to the agricultural sector?

YES NO

3. What types of weather/climate information does the department produce or access from other sources, and release to the public? (Please see examples for clarity). (Use an 'X')

Type of information	Produced	Sourced from others	Distribute
Daily/weekly forecasts (Future)			
Long-term (3 month/Seasonal) predictions (Future)			
Own weather recordings (Past)			
Historical rainfall/temperature records (Past)			
GIS generated maps showing climatic variables (Past)			
Other:			

4. What mechanisms do you use to distribute information?

Source	Method Used	Name of publication
Internet		
Newspaper		
Radio		
TV		
Report		
Other:		

5. Do you think you are producing a sufficient amount of information for people to interact with? Especially farmers in planning their year?

YES NO NOT SURE

Future Climate Change Information

6. Do you think future climate change scenarios (specific to your region) will be of interest to farmers in Pandamatenga?

YES NO NOT SURE

7. Do you know of potential impacts of climate change that could affect you and your area?

YES NO

If yes please provide a few examples you know of (e.g. heat stress, rainfall changes)

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8. Would you like to be more aware of climate change and its impacts specific to your region?

YES NO

Please explain why:

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Open-ended discussion questions (ask for recording)

9. How do you think you could improve your current products on weather and climate and perhaps include more products for distribution?

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10. Does the Meteorological Department (or other department) in Botswana release weather or climate warnings to you? (Such as projected drought, or storm occurrence)?

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11. Do you work with other Government departments or Non-governmental institutions on research and adaptation planning for climate change?

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12. Do you think there is adequate knowledge on climate change in Botswana to promote adaptation strategies?

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13. Further interrogation and interview as needed