# Preparing for the future: Assessing the vulnerability of small-scale farmers in Bushbuckridge

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## Abstract

Farming is a precarious profession, impacted by the social, economic, political, institutional and physical environment, to which climate change projections pose an additional challenge. South Africa has a highly diverse agricultural sector, with agricultural systems ranging from subsistence farming in homesteads to commercial estates with thousands of hectares under cultivation. In order to inform agricultural adaptation strategy and action, this thesis takes a multidisciplinary approach that focuses on preparing for the future by understanding the present. The focal aim of this thesis is to assess whether the current coping and adaptation mechanisms of small-scale farmers in the South African Province of Mpumalanga are sufficient for dealing with projected climate change. This is achieved through assessment of how small-scale farmers are currently coping with and adapting to climate variability and extreme weather events. A theoretical framework for vulnerability assessments, that situates farmers in a multi-stressor environment, is employed in order to get an understanding of the multifaceted setting in which small-scale farmers currently live and work. Farmers' understanding of the current climate is analysed through a comparison of local historical climate data with farmers' perceptions, while analysis of downscaled climate change projections provides a picture of what the future climate might look like. The study combines fieldwork data with historical and projected climate data from local stations in a combination of qualitative and quantitative data analysis, producing a number of findings that contribute to the discourse on adaptation, and further work to inform future policy and adaptation action.

# 0. Table of Contents

## List of tables

## List of Figures

## List of Pictures

# 1. Introduction

According to the Intergovernmental Panel on Climate Change's (IPCC) fourth assessment report (2007a) on impacts, adaptation and vulnerability, agricultural production in Africa is likely to be severely impacted by climate change. Yield potential, length of growing season and areas suitable for agriculture are projected to decrease, and rain-fed agriculture could face a yield reduction of up to 50% by 2020. In South Africa only 10% of the 15.5 million hectares of arable land is irrigated (Food and Agriculture Organisation of the United Nations (FAO), 2009), and farming practices range from subsistence and emerging to commercial. Farming is a precarious profession, impacted by the social, economic, political, institutional and physical environment, to which climate change projections pose an additional challenge (Morton, 2007; Meinke et al., 2006; Risbey et al., 1999; O'Brien et al., 2004b; Smit and Skinner, 2002).

With a complex history of several hundred years of racial exploitation and unequal resource distribution, inequality is still evident in the South African agricultural sector after many years of democracy (Banda, 2007). The formation of a united and prosperous agricultural sector has been a government focus since the end of the apartheid era, but the progress has been slow and conditions for small-scale farmers have not changed much (Banda, 2007). The agricultural sector mainly consists of small-scale farmers who make up 86% of the farming population, while only accounting for 10% of the value added by the agricultural sector (Benhin, 2006). Estimates indicate that there are four million people involved in small-scale agriculture, out of which the majority are located in what used to be apartheid homeland areas[1] (Baiphethi and Jacobs, 2009). A large proportion of the small-scale farmers are practicing subsistence agriculture (Benhin, 2006), but the definition also includes farmers who produce to sell.

In light of the potential impacts of climate change on agricultural activity and crop productivity, researchers have highlighted the need to make relevant knowledge and information accessible to farmers (Challinor et al., 2007). This is



[1] As part of the apartheid policy, the homelands were the areas assigned to Black Africans.

in order to inform and build sound agricultural adaptation, which can be defined as long term, sustainable adjustments (Smit and Wandel, 2006) aimed at maintaining farming objectives when faced with changing conditions (Risbey et al., 1999). Some challenges have been recognised in the research related to climate change adaptation and vulnerability. This includes the complexity and inter-related nature of climate change and agriculture, which requires multidisciplinary approaches (Howden et al., 2007) that further investigate the underlying climate parameters and conditions that shape vulnerabilities (Ziervogel and Ziermoglio, 2009). What is more, seeing coping as a distinct part of vulnerability, Eriksen et al. (2005) argue that the dynamism of coping and vulnerability needs to be understood in order to develop adaptation strategies. Research aimed at informing adaptation strategy and action in agriculture should thus focus on multidisciplinary approaches that account for underlying factors and dynamisms. What is more, research on small scale, and village level assessments is needed (Gbetibouo and Ringler, 2009), as vulnerability to climate variability and change is community specific (Smit and Wandel, 2006).

Village and community level assessments are also important in that they can dip into the experience and knowledge found among farmers. The importance of integrating local and traditional knowledge with scientific research and knowledge production has been well recognised in literature (Veedwan and Rhoades, 2001; Roncoli et al., 2002; Stigter et al., 2005; Meinke et al., 2006). The IPCC (2007a) has also recognised the value of indigenous knowledge studies in providing information for climate change impact, adaptation and vulnerability (CCIAV) assessments, particularly in areas where formal data records are sparse. As argued at a meeting at the Tyndall Centre in 2001, research that reflects lived experiences of coping with climate variability in resource-dependent communities should be prioritised. The experience from these studies, it was argued, will aid the development of international action on adaptation (Adger et al., 2003).

Research is also focusing increasing attention on thresholds (Eakin and Luers, 2006). The two main threshold categories being investigated in adaptation research include the thresholds that represent the point where adaptation first occurs and the thresholds that focus on the point where adaptation actions no longer reduce vulnerability, also referred to as limits to adaptation (Adger et al., 2009b). Such research can inform adaptation action, identifying thresholds before they have been reached. Research on adaptation thresholds in practice is limited, reflecting the need for further research in this area.

Focusing on small-scale farmers in South Africa, this research aims to address some of the important aspects and research gaps outlined above. In order to inform adaptation strategy and action, it takes a multidisciplinary approach that focuses on preparing for the future by understanding the present.

The central question to be addressed through this research is

> *Are current coping and adaptation mechanisms sufficient for farmers to deal with projected climate change?*

The research will be addressed through the following objectives:

1. Assess the historical nature of the main climatic stressors, and how the historical records corresponds with farmers' perceptions

2. Conduct a vulnerability analysis which looks at differential vulnerability to climate variability and extreme weather events, while also taking socio-economic and political issues into account

3. Analyse the different mechanisms by which farmers are coping with and adapting to climatic stressors, and consider potential adaptation thresholds

4. Assess what the local climate in Bushbuckridge is projected to look like into the future, and how the farmers are likely to be impacted by projected climate change

5. Discuss potential limits to adaptation and propose options and strategies that can enable small-scale farmers to deal with current challenges and future change

## 2. Literature review

Climate change impacts are already evident, and it is clear that adaptation is necessary (Adger et al., 2009b). Adaptation to climate change refers to adjustments that moderate impacts, taking advantage of new opportunities or dealing with the consequences (Adger et al., 2003), and is a political as well as a social process (Adger et al., 2009b). For many years, the focus of the international climate policy debate was primarily related to mitigation,[2] but in recent times adaptation to climate change has become an integral part of the conversation about the economics and politics of global climate change (Adger et al., 2009a). Accordingly, climate change adaptation research, having long focused on the nature of climate change, seems to have experienced a shift over the last few years, towards an increased focus on policy, more specifically on relevant applications and on how to adapt (Ziervogel and Ziermoglio, 2009).

### 2.1 Agricultural adaptation to climate variability and change

Agriculture, especially African agriculture, is one of the sectors currently experiencing extensive focus in the climate change literature. Over the last ten years literature has analysed agriculture through a number of approaches, including adaptation to climate change (Smit and Skinner, 2002; Howden et al., 2007; Ziervogel and Ziermoglio, 2009; Speranza, 2010), adaptation to climate change and climate variability (Risbey et al., 1999; Thomas et al., 2007) and perception of and adaptation to climate change and climate variability (Maddison, 2006; Gbetibouo, 2009; Mertz, 2009).

When assessing the way by which the agricultural development sector makes use of climate change scenarios for development of adaptation strategies, Ziervogel and Ziermoglio (2009) found that there tends to be a lack of understanding of the vulnerability and climate change context among organisations providing technical support to adaptation action. This lack of investigation into the underlying conditions and climate parameters responsible for climate change vulnerabilities, and how these might change into the future, could lead to misguided development and adaptation actions (Ziervogel and

[2] Mitigation here refers to the reducing the concentration of greenhouse gases in the atmosphere.

Ziermoglio, 2009). The study also identified a failure to include climate data currently being used in decision-making, including traditional knowledge, real-time data and historical data, when contextualising climate change risks in climate change adaptation endeavours. Ziervogel and Ziermoglio's (2009) study thus reflects a strong need for sound research that investigates agricultural adaptation actions in context of climate change and vulnerabilities, and which can inform practitioners and related actors in the agricultural development sector.

Howden et al. (2007) emphasise the importance of the integration of approaches. Recognising the urgency for agricultural adaptation to climate change, they argue that in order to step up adaptation action, climate change risk must be integrated with an inclusive risk management framework. What is more, they argue that the existing barriers to adaptation require a policy approach that is comprehensive and dynamic, focusing on a number of scales and issues. Howden et al. (2007) call for multidisciplinary approaches, scientific integration and strengthening of the interface with decision makers.



From a slightly different angle, Smit and Skinner (2002) attempt to outline types and levels of climate change adaptation available in the Canadian agricultural sector. Smit and Skinner (2002) argue for the importance of dissemination of information related to climate change vulnerability and risk, as well as a focus on a wide range of adaptations that stakeholders can consider. They find that rather than focusing on promotion of particular adaptations there should be a focus on increasing adaptive capacity, the ability of the agricultural sector to cope with opportunities and risks related to climate (Smit and Skinner, 2002).

Focusing on resilient adaptation of smallholder agriculture to climate change in Africa, Speranza (2010) recognises the need to strengthen the capacity in agriculture in order to cope with variable production environments. By developing and applying an analytical tool for assessing adaptation, the "resilience check," Speranza (2010, p.12) found that "buffer capacity, self-organisation and increasing capacity to learn and adapt (adaptive management) underpin adaptations." What is more, Speranza (2010) argues that adaptation is a continuum of practices, and there thus needs to be a mix of measures rather than one single measure for adaptation to climate change. Speranza (2010) further argues that reaching the very marginal areas and the very poor is still a challenge, but crucial if aiming to achieve sustainable adaptation to climate change. Speranza (2010) therefore proposes that public extension service should focus on the marginal areas and the poorest farmers, while private extension can support the high potential areas in the cash crop sector. Building of human capital can further avoid the pitfall of having to continuously target the poor, with education and training capacitating communities to provide their own extension and services (Speranza, 2010). Speranza (2010) thus identifies a need to focus on capacitating farmers to help themselves, especially through building of human capital in the marginal areas.

Taking a somewhat different perspective, Thomas et al. (2007) look at the nature of South African rainfall variability, considering the summer rainfall zone, and how farmers on the ground recognise and respond to variability. Their case studies showed how farmers recognise climate as a significant disturbance to their livelihoods, despite the numerous other stress factors affecting their lives. On a more general note, Thomas et al. (2007) argue that climate data can aid the understanding of differences in the drivers and the details of place specific adaptations, given that the appropriate methodologies for usage of that data are applied. Like Thomas et al. (2007), Risbey et al. (1999) also consider climate variability in their study of agricultural adaptation. Based on examples from Australian agriculture, Risbey et al. (1999) outline a model framework for investigating agricultural adaptation, providing insight into the role of climate change and climate variability in agricultural adaptation. Their findings highlight how climate change studies must incorporate the complexity of the adaptation process, including interactions across scales, background context and the limited information available.

While farmers have experience with climate variability, climate change might require adaptation of agricultural practices that are beyond farmers' experience (Maddison, 2006). What is more, farmers can't be expected to immediately pick up changes in the climate, and they are thus likely to experience a period of transitional losses (Maddison, 2006). According to findings by Maddison (2006), improved education amongst farmers is the most efficient way to hasten adaptation in Africa. Free extension advice and easier access and shorter distance to markets are other factors recognised as having the potential to improve and promote adaptation actions. Maddison (2006) further argues that only by perceiving climate change do farmers adapt, but that the perception depends on farmer experience and on the access to extension advice on climate change specifically. In the end though, Maddison (2006) recognises country specific differences in farmers' inclination to adapt that make further analysis into underlying factors necessary.

The studies outlined above reflect some of the important issues that have been raised in agricultural climate adaptation literature over the past years. One issue reflected in several of the studies is the complexity of adaptation, and the need for studies to incorporate background context and interactions across scales. It was also highlighted that an understanding of the underlying conditions that shape vulnerabilities are crucial to guide development and adaptation actions (Ziervogel and Ziermoglio, 2009). What is more, country specific differences in farmers' inclination to adapt require further analysis into underlying factors (Maddison, 2006). Farmers work in differential, multifaceted environments, where numerous factors shape vulnerabilities and drive or create barriers for adaptation action. These multifaceted environments motivate Ziervogel and Ziermoglio (2009) and Howden et al.'s (2007) call for integrated and multidisciplinary approaches to climate change and adaptation.

In a spatially focused study, Gbetibouo (2009) finds that many farmers in the Limpopo basin, South Africa, have been unable to adjust their farming practices to deal with perceived climate changes (that are also reflected in historical climate records). The main barriers, recognised by the farmers themselves, include access to credit, access to extension, off-farm activities, access to water, household size, experience, wealth and tenure rights. As was argued by Maddison (2006), Gbetibouo (2009) recognises how extension service information on weather and climate plays an important role in whether or not farmers perceive changes in the climate. More experienced farmers are also found to be more likely to perceive temperature changes. In the end Gbetibouo (2009) suggests that, in order to improve farmers' ability to adapt to climate variability and change, government policies should focus on: increased access to extension service and to affordable credit, creation of more opportunities for off-farm earning, investment in irrigation while also promoting efficient water use and strong management capacity.

Mertz et al. (2009), focusing on farmers in the Sahel, make somewhat different conclusions, arguing that policies related to agriculture and economic development should focus on flexible rather than specific options, in order to deal with the uncertainty of climate change. What is more, they find that while households are very much aware of climate variability, adaptation is driven by a number of factors, amongst which climate is not the most important one (Mertz et al., 2009).

Some of the studies outlined above explored the ways by which farmers' ability to adapt to climate variability and change can be improved. Mertz et al. (2009) note that there is a need for flexible rather than fixed solutions when dealing with an uncertain climate. General capacity building can be seen as a more flexible approach supported by several of the studies. While Gbetibouo (2009) argued for strengthening of farm-level management capacity to ensure efficient water use in irrigation, Speranza (2010) recognised the importance of building human capital, as education and training capacitates communities to help themselves. Accordingly, Smit and Skinner (2002) argued that the focus should be on increasing adaptive capacity, rather than on the promotion of particular adaptations.

## 2.2 Agricultural vulnerability to climate variability and change

As became clear in the review of climate adaptation literature above, promotion and implementation of agricultural adaptation to future climate change requires an understanding of the multifaceted environment in which farmers live and work. Vulnerability research presents methodologies that incorporate a number of different parameters, and which creates understanding of processes and outcomes (Adger, 2006). What is more, the method makes it possible to investigate the potential for pro-active adaptation (Adger, 2006). The vulnerability approach is therefore common in climate change research, where adaptation is reflected as an integral part of a complex system.

Vulnerability can in the most simple terms be defined as "the degree to which human and environmental systems are likely to experience harm due to perturbations or stress" (Luers et al., 2003, p.255). The term has numerous definitions and conceptual approaches, and has been used in many different academic fields. Accordingly, studies focusing on the vulnerability of farming systems also vary widely in their focus and approach.

One study, by O'Brien et al. (2004b), takes a progressive, multi-stressor approach, investigating regional and local vulnerability of Indian agriculture to economic globalization and climate change. The study uses a combination of vulnerability mapping and local level case studies, identifying regions of double exposure as well as outlining the role of local institutions in facilitating or creating barriers to adaptation at the village level. O'Brien et al. (2004b) argue that the regions of double exposure are those that most urgently need interventions and policy changes that help farmers deal with changes in the agricultural sector. Their approach made it possible to profile macro-level vulnerability to multiple stressors and to further investigate the differential vulnerabilities between villages and between farmers at the local level.

Taking a somewhat different approach, Challinor et al. (2007) investigate crop sensitivity to climate variability, farmer's adaptive capacity and the role of institutions in climate change adaptation. Challinor et al. (2007) find that a number of studies indicate that crop productivity in Africa will be negatively impacted by climate change, and that accessing relevant knowledge and information will be crucial for farmers' ability to adapt. For the African research community it is thus important that multidisciplinary expertise is maintained, and there should be research, across numerous disciplines, focusing on understanding coping strategies in African agriculture (Challinor et al., 2007).

Investigating the dynamics of vulnerability, Eriksen et al. (2005) analyse coping strategies among smallholder farmers in Kenya and Tanzania. Seeing coping as a distinct part of vulnerability, Eriksen et al. (2005) argue that the dynamism of coping and vulnerability needs to be understood in order to develop adaptation strategies. They highlight empowerment as an important part of adaptive strategy, and the need to see vulnerable people as active agents rather than passive victims. Eriksen et al. (2005) further argue that decision-making and policy intervention should not be rigid, and that approaches must thus account for the dynamic nature of different communities. Policy interventions should further work to support the determination and creativity inherent in communities (Eriksen et al., 2005).

A study examining the South African farming sector's regional vulnerability to climate change and variability further highlights the need to develop region-specific policies, focusing on local level climate change (Gbetibouo and Ringler, 2009). The study finds that there are large differences in the provincial vulnerability to climate change and variability across the country, and that the differential vulnerability is connected to social and economic development. For example, Limpopo was identified as the overall most vulnerable region in the country, but has only a medium risk of exposure to drought, floods and projected climate change. On the other hand it is one of the most sensitive regions and has the second lowest adaptive capacity, "potential to implement adaptation measures that help avert potential impacts," in the country (Gbetibouo and Ringler, 2009, p.8). The sensitivity, the internal structures that shape people's ability to cope and recover (Kapland et al., 2009), can be related to Limpopo's many small scale subsistence farmers, the high proportion of rain-fed agriculture and lack of more advanced technology, as well as inappropriate use of land, leading to reduced production capacity and land degradation (Gbetibouo and Ringler, 2009). Undeveloped infrastructure, prevalence of HIV and unemployment together with high agricultural dependency make for a low adaptive capacity in the region. With its high sensitivity and low adaptive capacity Limpopo is not likely to cope effectively even with moderate climate changes (Gbetibouo and Ringler, 2009). Western Cape, on the other hand, is found to have the lowest vulnerability, mainly due to its high adaptive capacity and low potential impacts. While Gbetibouo and Ringler's (2009) analysis brings about an understanding of regional vulnerability, the study argues that new research should focus on small scale, district and village level assessments. While district level assessments are currently difficult to execute in South Africa due to limited data (Gbetibouo and Ringler, 2009), community scale vulnerability research can be conducted through engagement with farmers. Previous community scale research has illustrated that vulnerability is community specific (Smit and Wandel, 2006), and it can be argued that this is particularly so in the South African agricultural sector where farming practices are highly diverse and operate at very different spatial scales.

The studies outlined above show how focus and approach can differ within vulnerability research on agriculture and climate change. The studies reflect the value of analysing coping as embedded in a vulnerability context, and highlight the need for policy interventions that account for different regional and local dynamics. This further reflects the need for research focusing on small scale, district and village level assessments, as highlighted by Gbetibouo and Ringler (2009). The latter study also illustrates the role of social and economic development in the vulnerability to climate variability and change, supporting Challinor et al.'s (2007) argument for the emphasis on multidisciplinary research. A number of studies have argued that interacting biophysical and socio-economic factors together shape vulnerability (Cutter et al., 2000; Benhin, 2006; Casale et al., 2009; Speranza, 2010), thus further supporting the need for multidisciplinary approaches to research concerning vulnerability to climate variability and change.



## 2.3 Thresholds

While often related to the identification of thresholds of dangerous climatic change for mitigation purposes, thresholds are now receiving increased attention in research concerned with vulnerability and social and environmental change (Eakin and Luers, 2006). Literature tends to focus on critical biophysical and ecological thresholds, but some research is starting to explore the use of thresholds in management and adaptation. Using a general definition Adger et al. (2009b, p.6) refer to a threshold as "a level or point at which something starts or ceases to happen or come into effect," and argue that most thresholds for adaptive action fall within two categories. The first category is concerned with the thresholds where adaptive actions initially take place, the point where responses are made to reduce the vulnerability to climate change. The second category is concerned with the thresholds beyond which adaptive actions no longer reduce vulnerability, and can be thought of as the limits to adaptation (Adger et al., 2009b).

Focusing on the agricultural sector in New Zealand, Kenny et al. (2000) look at multiple and inter-related thresholds, including managerial and geographic. Concerned with the thresholds where adaptations first take place, they identify the mean temperature beyond which kiwi fruit growers would have to increase their chemical management in order to maintain their yield. Research in the field of biological engineering, has also investigated the threshold where adaptation first takes place. Hahn (1999) assesses how cattle respond to heat, identifying a temperature threshold beyond which the cows are stressed by the heat, thereby informing farmers on the optimum environment for cattle and also the point where adaptive action is necessary. A more recent study by Reeder et al. (2009) looks at adaptation thresholds that relate to what Adger et al. (2009b) referred to as the point beyond which the adaptive action no longer reduces vulnerability. Concerned with sea level rise and tidal flooding in London, Reeder et al. (2009) investigate different engineering options and the sea level rise beyond which the different options no longer act as efficient barriers or buffers.

These three studies illustrate the use of both threshold categories outlined by Adger et al. (2009b). Such assessments as those outlined above can support pro-active management, both in agriculture and in other fields, and can thus inform the need for adaptation actions before thresholds have actually been crossed. While there is a discourse emerging on Adger et al.'s (2009b) second category of thresholds, the limits to adaptation to climate change (Adger et al., 2009b), there seems to be limited literature available on practical examples. This reflects the need for more research that investigates thresholds that reflect limits to adaptation.



## 2.4 Future climatic change

Ziervogel and Ziermoglio (2009) highlighted the importance of focusing on the development of methods and examples of how climate change projection outputs can be used to underpin adaptation in different sectors. The importance of the various climatic variables differs in different sectors, and when focusing on the agricultural sector it is thus important to focus on the climatic variables that are important for farming practices. According to Jennings and Margrath (2009), analysis of climate change projections tend to focus on mean changes in precipitation and temperature, rather than on subtle changes in the rainfall patterns that significantly impact for example smallholder farmers practicing rain-fed agriculture. Accordingly, while recognising rainfall as the climate parameter that most significantly impacts human activities, Thomas et al. (2007) argue that drought and extreme rainfall may not sufficiently capture the characteristics that are important for agricultural decision-making. For example, timing of the onset of first rains and the effectiveness of rains are other criteria crucial for farming success (Thomas et al., 2007). At the same time, skills for capturing rainfall are somewhat poor in the General Circulation Models (GCMs) (Challinor et al., 2007; Speranza, 2010), further complicating the use and application of projected rainfall data in impact studies and adaptation planning. For the purpose of this research study, the aim has thus been to investigate climatic characteristics relevant to farmers, though within the scope of what has been possible in this study.

# 3. Conceptual Framework and Theoretical approach

## 3.1 Adaptation, coping and vulnerability

The terms coping and adapting are similar and often only loosely, if at all, defined in literature. In his assessment of knowledge on and approaches to vulnerability to environmental change, Adger (2006) questions whether there is actually any distinction between coping and adapting. That same year Smit and Wandel (2006) highlight how some researchers distinguish between the two by seeing coping as concerned with the short-term capacity or ability to survive, and adapting as dealing with sustainable, more long-term adjustments. This distinction will also be the approach of this research.

Füssel (2007) argues that due to the diverse contexts of adaptation, assessments should focus on specific circumstances of decision situations. Literature has also highlighted how there are many drivers of change of which climate change is just one (Jones, 2001), and that it can be difficult to single out climate as the driver of coping and adaptation strategies (Mertz et al., 2009). Assessment frameworks should thus include multiple drivers, or be compatible to similar frameworks (Jones, 2001). According to Füssel (2007), there have been two approaches to climate impacts and adaptation assessments, namely the vulnerability-based approach and the hazards-based approach. While the latter focuses on the increasing impacts of climatic change, the former considers future climate change in relation to current climatic risks (Füssel, 2007). The term vulnerability, which in its most basic sense is concerned with "the capacity to be wounded" (Kasperson et al., 2005, p.146), has become part of the terminology of disciplines ranging from economics to anthropology and human geography (Adger, 2006). The use of the term in different fields has given it different meanings and assessment frameworks (Smit and Wandel, 2006) that are all confusingly interlinked. For example, while Füssel (2007) sees the vulnerability approach as separate to the hazard based approach, others have seen the hazard approach as being one of the antecedent traditions to vulnerability (Adger, 2006; Eakin and Luers, 2006).

The different assessment frameworks that have emerged from the complex myriad of vulnerability research, from diverse strands of academia, can lead to different approaches to the solution of the problem (O'Brien et al., 2004a). O'Brien et al. (2004a) describe two research interpretations of vulnerability, namely the end point and the starting point approach. The end point approach starts with the future emission trends and climate scenarios, focusing mainly on biophysical impacts and specific adaptation options. It sees vulnerability as the impact of the climate problem minus adaptations, and tends to focus on technological solutions and technology transfers (O'Brien et al., 2004a). The starting point approach, on the other hand, is concerned with the present, focusing on current capacity for coping with stress and change. It sees vulnerability as "a characteristic of social and ecological systems that is generated by multiple factors and processes" (O'Brien et al., 2004a, p.2). These two approaches are thus driven by quite different issues, the former by the question of whether the mitigation benefits will override the costs of reducing emissions, and the latter by the aim to identify how vulnerability can be reduced (O'Brien et al., 2004a). O'Brien et al. (2004a) further argue that the crucial difference between the two analytical approaches is their look on adaptation. With vulnerability as a starting point vulnerability is seen as determining adaptive capacity and adaptations, while with vulnerability as an end point vulnerability is seen as determined by adaptive capacity and adaptations (O'Brien et al., 2004a).

In a more recent paper O'Brien et al. (2007) redefine the definitions, as they find that 'outcome vulnerability' is a better summary of the end-point approach and 'contextual vulnerability' a better summary of the starting-point approach. As aligned with its forerunning definitions, outcome vulnerability "is considered a linear result of the projected impacts of climate change on a particular exposure unit, offset by adaptation measures," while contextual vulnerability considers multidimensional climate-society interactions, considering both climate variability and change in relation to changes in social, political, economic and institutional factors (O'Brien et al., 2007, p.75-76). While the different definitions and approaches to vulnerability can cause confusion, it has been argued that a diversity of approaches is necessary to deal with the complexity of vulnerability (Eakin and Luers, 2006). As O'Brien et al. (2007) find, the outcome and contextual vulnerability interpretations are complementary, and should not be integrated into one framework.

Turner and his colleagues (2003a) in the Research Assessment Systems for Sustainability Science Program tried to create an integrative framework, and the outcome can be seen as a formalisation of the contextual vulnerability interpretation approach. The framework was developed to assess vulnerability in an integrative manner, within the context of coupled socio-ecological systems (SES).[3] As was argued by Adger (2006) concepts of vulnerability of SES are developed through the conglomeration of approaches to vulnerability in all other disciplines. Turner et al. (2003a) state that their approach draws heavily on work done in climate impacts, risk hazards and entitlement research. The framework has made specific use of lessons learned from the risk-hazard (RH) and the pressure-and-release (PAR) model (Turner et al., 2003a). Turner et al. (2003a) have worked to include components that could not be found in the other models, such as the PAR model's failure to address the full coupled human – environment system, and to sufficiently emphasise feedbacks that work beyond the scale of the system of analysis and to provide the causal sequences of the hazards. Building on various research traditions and addressing shortcomings of other studies has resulted in a framework that incorporates both external and internal socio-economic, biophysical and climatic elements, as can be observed in figure 3.1 below. The framework frames vulnerability in the context of SES, and incorporates vulnerability to human and environmental variability and change. It considers the elements of vulnerability, namely resilience, sensitivity and exposure, in a bound system, and works to elaborate the coupled character of mechanisms and processes.



[3] Also referred to as human-environment systems.

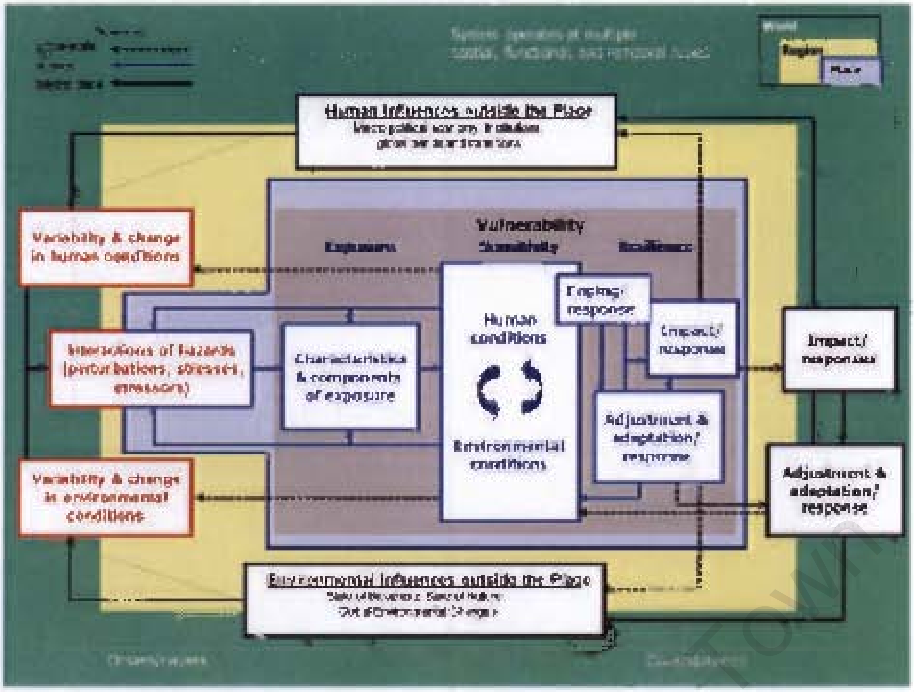


**Figure 3.1 Integrative vulnerability framework.** (Source: Turner et al., 2003a, p.8076)

The applicability of the framework is challenged by its complexity, which may require large financial resources as well as substantial interdisciplinary teams (Eakin and Luers, 2006). After illustrating the use of the framework Turner et al. (2003b) acknowledged this, stating that conducting the complete vulnerability assessment is a very difficult task, possibly beyond the capacity of most research initiatives. Turner et al. (2003b) further argue that the framework provides a good point of departure for vulnerability assessments, and that it should be modified according to the system to which it is applied.

## 3.2 Applying the Turner et al. (2003a) framework and defining the concepts

One of the important elements of this research is to understand the context within which small-scale farmers in Bushbuckridge live and work, and to further assess their differential vulnerability to climate variability and extreme weather events. The approach is thus based on the contextual vulnerability interpretation, and focuses on understanding current vulnerability to climatic factors, while at the same time incorporating the socio-economic elements of farmers' everyday life. Further recognising the value of integrative vulnerability frameworks, this research has chosen Turner et al.'s (2003a) framework as a point of departure. Though acknowledging the value of the coupled nature of the framework, this research has had to limit itself to a more simplified approach that does not account for all the feedbacks and links of the Turner et al. (2003a) framework.

Turner et al. (2003a, p.8074) define vulnerability as "the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor." This study embraces the definition, and investigates the degree to which farmer households are likely to experience harm based on their sensitivity and resilience, and their exposure to climate variability and extreme weather events using vulnerability indicators. It further investigates socio-economic and political stress through qualitative elaboration of the main problems that farmers face in everyday life. In the absence of studies with similar, local scale approaches to which the farmers' vulnerability can be compared or weighted, focus is on comparison between the vulnerability of the eastern and the western villages.[4]

In vulnerability research exposure has been referred to as "the degree, duration and/or extent to which the system is in contact with, or subject to, the perturbation" (Gallopin, 2006, p.296). The perturbation can be related to both environmental and socio-economic stress (Adger, 2006), but in this research it will mainly focus on climatic stress, more specifically climate variability and extreme weather events.

When assessing sensitivity Turner et al. (2003a), look at the human-environment conditions within the system that determine the degree to which it is modified or affected by their exposure to stressors. As outlined by Kaplan et al. (2009, p.1480), in the application of the framework, sensitivity is shaped by "the internal structure of a society and the livelihoods within this society, which shape the ability of people to cope and recover from hazards". Turner et al. (2003a) refer to social and human capital and endowments as well as the natural capital and the biophysical endowments within a system as the determinants of

[4] The differences between the western and the eastern villages will be outlined in detail in section 4.2.

sensitivity. This research will thus assess sensitivity by looking at the internal structures that determine the degree to which a farmer is threatened by climate variability and extreme weather events, including education, irrigation and crop damage from extreme weather events.

The concept of resilience stems from the ecological sciences, but is also made applicable in social science and SES (Gallopin, 2006). Adger et al. (2006, p.268-269) state that, in the context of SES, "resilience refers to the magnitude of disturbance that can be absorbed before a system changes to a radically different state as well as the capacity to self-organise and the capacity for adaptation to emerging circumstances." This is in line with resilience as referred to by Turner et al. (2003a), a system's ability to cope or respond to disturbances acting from both within and beyond the system. As was highlighted by Kaplan et al. (2009), Turner et al.'s (2003a) approach to resilience allows for assessment of both immediate coping as well as the adaptation to changing conditions. This research will thus assess resilience by looking at the factors that shape farmers' ability to cope and respond to climate variability and extreme weather events, including off-farm employment, government support, support from friends and family, access to agricultural insurance, access to credit, membership in farm organisations and degree of crop diversification.

When using resilience as one of three elements of vulnerability it is important to note that some frameworks, such as that referred to by the IPCC (2001), use the concept of adaptive capacity rather than resilience, and to note how the two concepts relate. Adaptive capacity has been defined as "the ability or potential of a system to respond successfully to climate variability and change" (IPCC, 2007b, p.727), a definition that is not very different from that of resilience. While the IPCC referred to resilience as the flip side of vulnerability (2001), Gallopin (2006) showed how vulnerability does not appear to be the opposite of resilience. Instead, Gallopin (2006) recognised resilience as related to one of the components of vulnerability, and as a concept that is variously also called adaptive capacity. This relates to the approach taken by the Turner et al. (2003a) and thus that of this research.

### 3.3 Adaptation thresholds

As outlined earlier in this section, this study sees coping as short-term responses and adaptation as long-term adjustments. A study on household responses to climate, water and health stressors, by Ziervogel et al. (2006b), gives a more practical sense of coping versus adaptation. Separating the two, the study outlines adaptation strategies that include contacting the district authority for support, trying to access grants and finding work elsewhere. Coping strategies outlined include borrowing food, buying food on credit and limiting portion sizes. Hence while coping is concerned with day-to-day responses, adaptation works over a longer time frame and reflects a larger change in practices. In a study from Sekhukhune, South Africa, it was found that while people would prefer long term, sustainable ways of dealing with stressors, they often have to resort to short-term coping mechanisms (Ziervogel and Taylor, 2008). As highlighted by Schulze (2007), coping with urgent issues, such as basic water supply, tend to override the focus on longer-term ability to adapt in developing countries such as South Africa.

In the agricultural context, Risbey et al. (1999, p.138) define adaptation as "the process of maintaining various farming objectives (e.g. yield, production, profitability, sustainability) in the face of changes in external conditions." In relation to adaptation research, the importance of assessing the limits to adaptation has further been recognised (IPCC, 2007a). As was outlined in a previous section of this research, there are limits to adaptation, thresholds beyond which adaptive actions no longer reduce vulnerability (Adger et al., 2009b). Accordingly, this research looks at adaptation mechanisms in more details, focusing on limits to agricultural adaptation, a point beyond which farming objectives, under current practices and adaptation mechanisms, are no longer maintained. More specifically, it focuses mechanism for responding to specific climatic stressors, and works to identify the amount of stress that the farmers are currently able to deal with, using their present coping and adaptation mechanisms, while still maintaining their farming objectives. The thresholds are further analysed in relation to climate change projections for the future, and the degree to which current coping and adaptation mechanisms are sufficient for small-scale farmers to deal with projected climate change.

# 4. Methodology

## 4.1 Site selection

The study area is located in the north-eastern part of South Africa, and is one of the two case study areas which had been chosen, based on the climatic conditions and agricultural activities and systems, for the larger project with which this research is associated. Bushbuckridge Local Municipality was chosen because, firstly, it is one of the areas in South Africa where climate change projections indicate quite significant increases in temperatures as well as some indications of drying in the middle of the rainy season (Tadross et al., 2011). Secondly, because it has a large number of small-scale and subsistence farmers, practicing both rain-fed and irrigated agriculture, as well as commercial farmers. What is more, the area has a complex background and many socio-economic challenges. This combination of climatic, agricultural, economic and social factors makes Bushbuckridge an interesting site for community specific research into the livelihoods of small-scale farmers and the potential impacts of climate change.

Site visits with interviews and follow-up focus group discussions were made at four villages in the Bushbuckridge Local Municipality. It was important to locate villages that featured irrigation agriculture, as well as villages that featured rain-fed agriculture, as the research aimed to investigate both farming systems. Two villages featuring irrigation schemes, New Forest and Dingleydale, were therefore identified and chosen based on the researcher's ability to establish reliable contacts within the schemes. Accordingly, two villages featuring rain-fed agriculture, Motlamogatsane and Phelandaba, were identified and chosen based on the researcher's ability to establish reliable contacts in the villages.

## 4.2 The Study area


**Figure 4.1: Location of study area** (BT and Dplg, 2007, p.7)

Bushbuckridge Local Municipality was established in the year 2000 from the merge of three Transitional Local Councils (BT and Dplg, 2007). The area used to be designated bantustan homelands under the apartheid government up to 1994, and the area and its history is dominated by migrant labour, forced resettlement and villagisation (Biggs et al., 2007). The municipality was initially spread across Limpopo and Mpumalanga, but became fully integrated into Mpumalanga in recent years, under the Ehlanzeni District Municipality. The Bushbuckridge Local Municipality covers 2123 $km^2$ and has a population of just under 500 000 people, spread across rural settlements and 235 villages (BT and Dplg, 2007). It is an area facing many challenges, with 85% of the population living under the poverty line,[5] with 40% of the residents having no education and with only 29% of residents having access to piped water in close proximity, (within 200 m of their home) (BT and Dplg, 2007). Agriculture is one of the four distinct sub-economies in the municipality, which also include government and public service, services and retail, and tourism. There is limited presence of commercial farming and only 8% of formal employment in the municipality is in the agricultural sector. Large estates that used to be the big sources of employment now lie dormant, and the majority of farmers operate at small-scale or subsistence levels (BT and Dplg, 2007). Some of the small-scale and



[5] Below the household subsistence level of R19 200 a year (BT and Dplg, 2007).

subsistence farmers work in what used to be commercial estates, run by the Department of Agriculture and the Gazankulu Development Corporation. These are now schemes run by the farmers themselves, with some assistances from extension officers. According to the Nodal Economic Profiling Project (BT and Dplg, 2007) there is potential for the fruit and vegetable sectors in the municipality. "From an 'emerging farmer' perspective, land and labour are available but knowledge, skills and equipment are lacking" (BT and Dplg, 2007, p.72).

Bushbuckridge Local Municipality features rocky ridges and sandy plains, dominated by tropical bush and savannah, but with some inland tropical forest in the west. On the eastern border of the municipality you find the Kruger National Park, and on the western border the Blyde River Canyon. The municipality is mainly semi-arid, but with dry sub-humid to humid zones to the west.

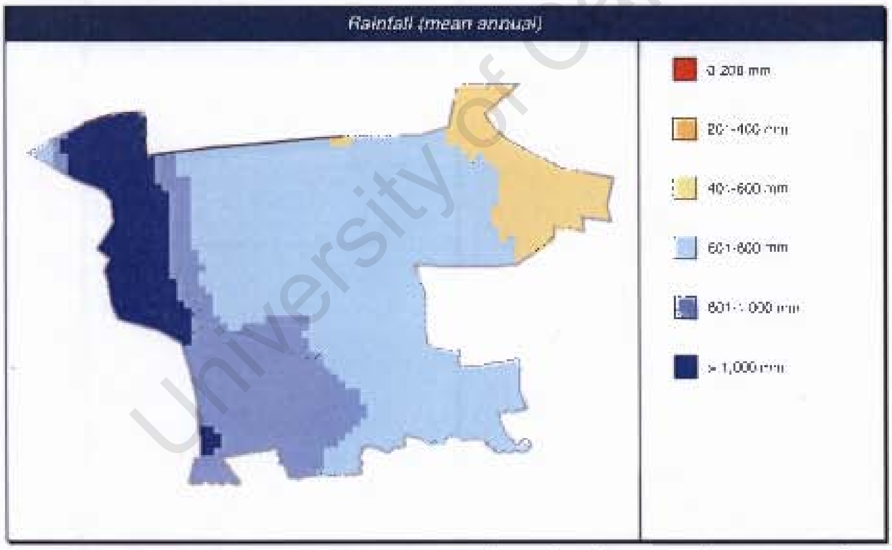


**Figure 4.2: Mean annual rainfall in Bushbuckridge Local Municipality.** (Source: BT and Dplg, 2007, p.17)

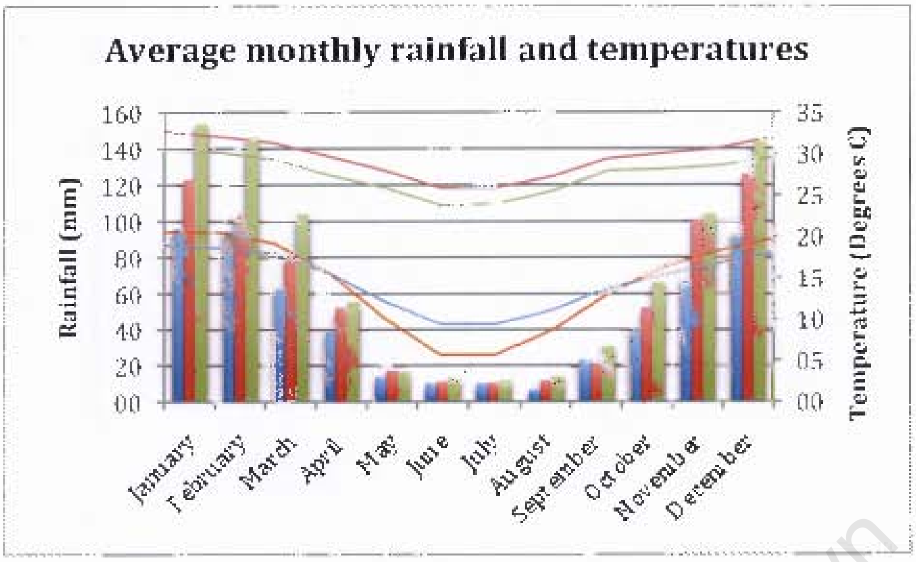


**Figure 4.3: Average monthly rainfall and maximum and minimum temperatures (historical).**[6]

The villages lie at relatively similar altitudes, ranging between 485 meters (New Forest) and 650 meters (Motlamogatsane) above sea level. Climate change projections for the area indicate approximately two degrees increase in mean monthly temperatures through the year by the middle of this century, as well as drying in the middle of the rainy season (December, January and February) (Tadross et al., 2011).



[6] Data is based on the period 1960-1995. Rainfall data is from Skukuza, New Forest and Pretorisukop and temperature data is from Skukuza and Pretoriuskop.

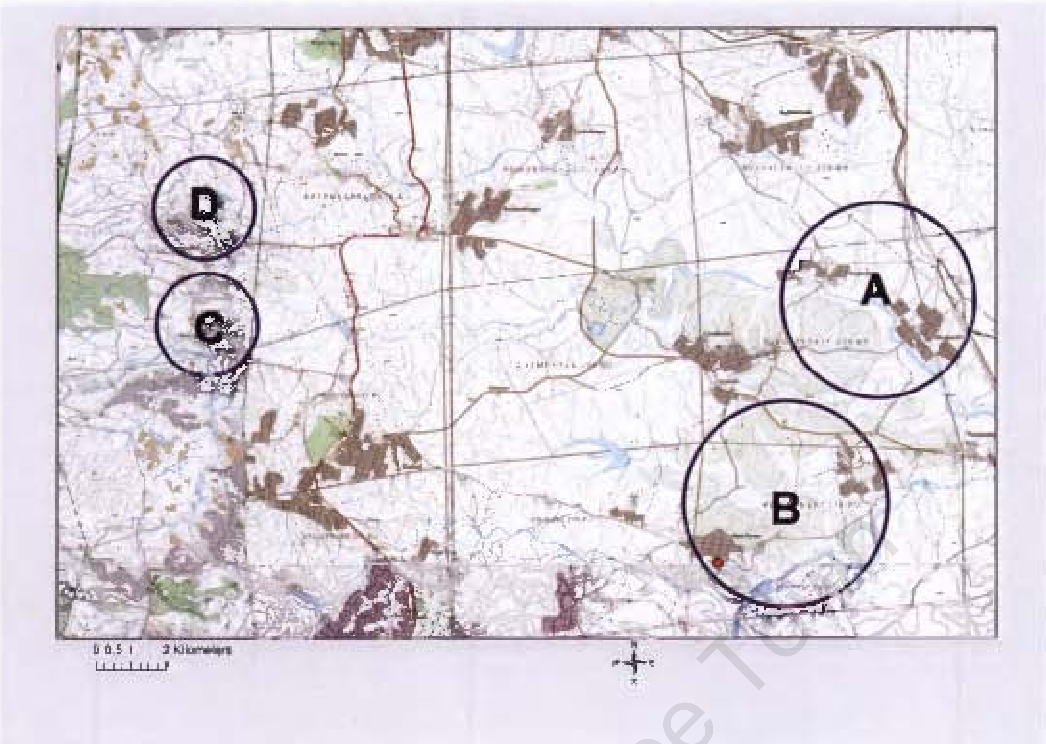


**Figure 4.4: The Bushbuckridge area with the four study sites:**
A) Dingleydale, B) New Forest, C) Phelandaba and D) Motlamogatsane
(Source: GIS maps, using National Geo-spatial information, Department of Rural Development and Land Reform)



The research included questions on land ownership, but towards the end of the study it became clear that farmers would interchangeably say that they own the land and that they have permission to occupy (PTO). While this reflects a somewhat confused perception of ownership from the farmers' side, it also means that it was not possible to use the data collected in relation to ownership of land. This is an important aspect that should be investigated further in future studies.

The farmers interviewed in Motlamogatsane and Phelandaba mainly practice rain-fed subsistence farming, with some selling to markets in the area, and have fields in their homestead, in the wetland by the village and some also in the mountains nearby, the farmers interviewed in New Forest and Dingleydale work with irrigation systems in irrigation schemes and sell some or a lot of their produce to local markets and towns in the wider area. Due to their location and similarities the former are referred to as the western villages, and the latter as the eastern villages. The villages are described in some more detail below.

## 4.3 Eastern villages

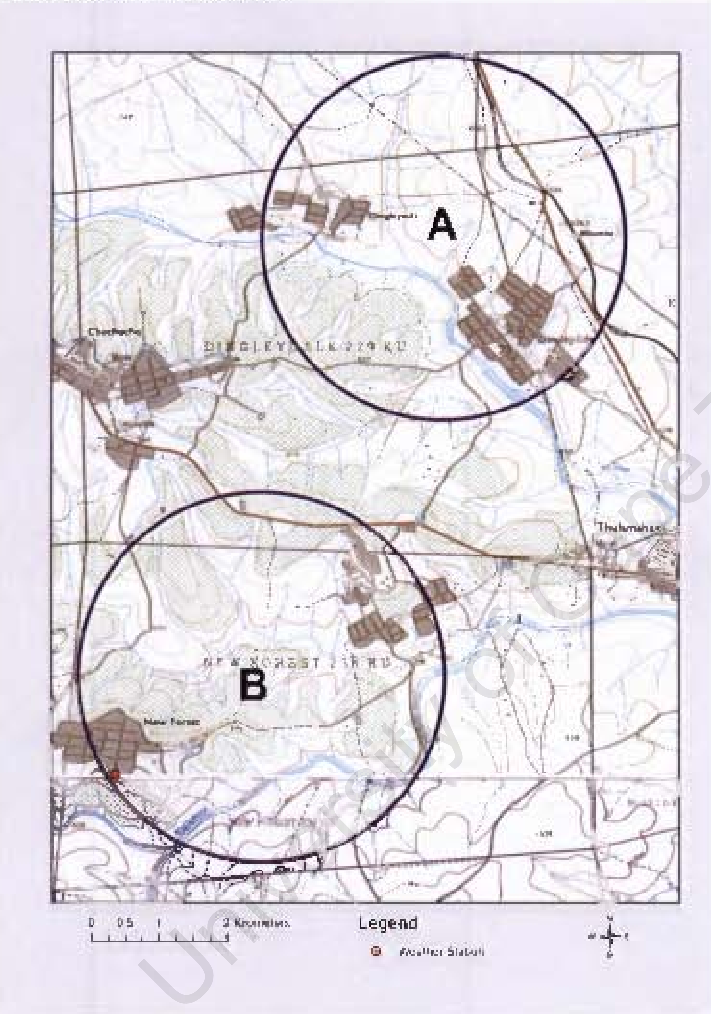




**Figure 4.5: Overview of the eastern villages:**
A) Dingleydale, B) New Forest (Source: GIS maps, using National Geo-spatial information, Department of Rural Development and Land Reform)

In the eastern villages, New Forest and Dingleydale, farmers work together in schemes, sharing flood irrigation systems comprising a number of dams and canals. The schemes are run by the farmers themselves, but are based on what used to be irrigation schemes that were initially developed and run by the

Department of Agriculture and the Gazankulu Development Corporation,[7] and later by the Agricultural and Rural Development Corporation (ARDC). New Forest irrigation scheme used to cover 120 hectares, have close to 500 permanent employees, and focus on vegetable and tobacco production, while Dingleydale irrigation scheme covered 700 hectares, had just over 600 employees and focused on vegetable production (BT and Dplg, 2007). The current size and number of farmers is unclear, but the farmers now have individual plots that seem to range between one and 15 hectares, as observed in the table below.

The most common crop grown in the eastern villages is maize, followed by tomatoes. Crops such as spinach, pumpkin, dry beans and beetroot are also relatively common. The farmers sell their crops at local markets, as well as to supermarkets and markets in towns in the wider area, including Thulamahashe, Hazyview, Hluvukani, Hoedspruit, Graskop, Acornhoek, Belfast, Bushbuckridge town, Phalaborwa and Nelspruit.



[7] Each homeland in Limpopo had its own development corporation. After 1994 all the development corporations were merged into the Agricultural and Rural Development Corporation (ARDC). The ARDC has since been closed down and transformed into another governmental directorate within the Limpopo Department of Agriculture.

| Eastern villages | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Farm** | **Plot size (ha)** | **Carrot** | **Cabbage** | **Tomato** | **Chilli** | **Spinach** | **Lettuce** | **Onion** | **Butternut** | **Peanuts** | **Pumpkin** | **Sweet potato** | **Sugarcane** | **Dry beans** | **Beetroot** | **Green pepper** | **Green beans** | **Maize** | **Bambara nuts** | **Cassava** | **Matlapala** | **Madumbis** | **Potato** | **Cow peas** |
| 1 | 3 | | √ | √ | | √ | | √ | √ | √ | √ | | | | √ | | | √ | √ | | | | | |
| 2 | 5 | | | √ | | √ | | √ | √ | √ | | | | √ | | | | √ | √ | | | | | |
| 3 | 3 | | | √ | | √ | | √ | √ | | | | | √ | | | | √ | | | | | | |
| 4 | 2 | | | √ | | | | | √ | | | | | | √ | | | √ | | | | | | |
| 5 | 2 | | √ | √ | | | | | | | | | | | | | | √ | | | | | | |
| 6 | 3 | | √ | √ | | | | | | √ | | | | | | | | √ | √ | | | | | |
| 7 | 8 | | | | | √ | | | | | √ | √ | | √ | | | | √ | | | | | | |
| 8 | 1 | | √ | √ | | √ | | | | √ | √ | | | √ | √ | | | √ | √ | | | | | √ |
| 9 | - | | √ | | | √ | | √ | | | √ | | | √ | | | | √ | | | | | | √ |
| 10 | 1 | | | √ | | | | | √ | | √ | | | | | | | √ | | √ | | | | |
| 11 | 1 | | | √ | | √ | | | | | √ | √ | | √ | | | | √ | | | | | | |
| 12 | 2 | | | √ | | | | | | | √ | | | | | | | √ | | | | | | |
| 22 | 3 | | √ | √ | √ | √ | | √ | √ | | √ | | | √ | √ | | | √ | | | | | | |
| 23 | 15 | | | √ | | √ | | | √ | | √ | √ | | √ | √ | | | √ | | √ | | | | |
| 24 | 1 | | | √ | | √ | | √ | | √ | √ | | | √ | √ | | | √ | | | | | | |
| 25 | 1 | | | | | | | | | | | | | | | | | √ | | | | | | |
| 26 | 1 | | | √ | √ | | | | | | √ | √ | | √ | √ | | | √ | | √ | | | | |
| 27 | 2 | | | √ | √ | √ | | | √ | | √ | | | √ | √ | | √ | √ | | | | | | |
| 28 | 1 | | | | | | | | | | | | | √ | | | | √ | | | | | | |
| 29 | 1 | | | √ | | √ | | | | | | | | | √ | √ | | √ | | | | | | |
| 41 | 3 | | √ | √ | | | | √ | √ | | | √ | | √ | √ | | | √ | | | | | | |
| 42 | 5 | | √ | √ | √ | | | | | | | | | | √ | | | √ | | | | | | |
| 43 | 1 | | | √ | | √ | | | | | √ | | | | √ | | | √ | | | | | | |
| Total | | 0 | 8 | 19 | 4 | 13 | 0 | 7 | 9 | 5 | 13 | 5 | 0 | 13 | 12 | 1 | 1 | 23 | 4 | 3 | 0 | 0 | 0 | 2 |

**Table 4.1: Crops grown by interviewees from the eastern villages.** The table outlines the crops commonly grown by each of the 23 interviewees from the eastern villages and their individual plot sizes.

The farmers in New Forest and Dingleydale irrigation scheme get assistance from extension officers, and have also been working together with the Maruleng & Bushbuckridge Economic Development Initiative (MABEDI). MABEDI was started and funded by Business Trust and implemented by ECIAfrica. It has been working with the farmers in New Forest and Dingleydale (as well as other with farmers in other irrigation schemes) the last four years on different issues, including transportation and marketing.

third field up in the mountains close to the villages. While the farmers do not measure the size of their fields, they were found to have between 1 and 15 of what they call beds in the wetland. While the beds are of various sizes, they can roughly be estimated to be plus-minus 2x3 meters.

The most common crops in the western villages are madumbis, a local root vegetable, and maize. The dominance of madumbis and maize reflects the focus on subsistence farming in the western villages, though it should be noted that some of the farmers also grow a number of other crops as reflected in table 4.1 below. While some farmers sell the occasional crop surplus at the local market, only two farmers interviewed sell crops beyond their village, in Acornhoek, one of the larger towns in Bushbuckridge Local Municipality.

| Western villages | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farm | Plot size (ha) | Carrot | Cabbage | Tomato | Chilli | Spinach | Lettuce | Onion | Butternut | Peanuts | Pumpkin | Sweet potato | Sugarcane | Dry beans | Beetroot | Green pepper | Green beans | Maize | Bambara nuts | Cassava | Matlapala | Madumbis | Potato | Cow peas |
| 13 | - | √ | √ | √ | | √ | | √ | | | | √ | | | √ | | | | | | √ | √ | | |
| 14 | - | √ | √ | √ | | √ | | | | | √ | | √ | | √ | | | √ | | √ | √ | √ | | |
| 15 | - | | | | | √ | | | | | √ | | | | | | | √ | | | | √ | | |
| 16 | - | | | | | | | | | | | | | | | | | | | | | √ | | |
| 17 | - | √ | √ | √ | | √ | | | | | | | | | √ | | | | | | | | √ | |
| 18 | - | | √ | √ | | √ | √ | √ | | | | | | | √ | | | √ | | | √ | √ | | |
| 19 | - | | √ | √ | | √ | | √ | | | | | | | | | | √ | | | | √ | | |
| 20 | - | | | √ | | | | √ | | √ | | √ | | | | | | √ | | √ | | √ | | |
| 21 | - | | √ | √ | | | | √ | | | √ | | | | | | | √ | | | | √ | | |
| 30 | - | | | | | | | | | | | | | | | | | √ | | | | √ | | |
| 31 | - | | | | | | | | | | √ | | | | | | | √ | | | | √ | | |
| 33 | - | | | | | | | | | √ | √ | √ | | | | | | √ | √ | √ | | √ | | √ |
| 34 | - | | | | | | | | | √ | √ | | | | | | | √ | | | | | | |
| 35 | - | | | | | | | | | | √ | | | | | | | √ | | | | √ | | |
| 36 | - | | | | | | | | | | √ | | | | | | | √ | √ | | | √ | | |
| 37 | - | | | | | | | | | | √ | | | | | | | √ | | | | √ | | √ |
| 38 | - | | | | | | | | | | √ | √ | | | | | | √ | √ | | √ | √ | | √ |
| 39 | - | | √ | | | √ | | | | √ | √ | | | | √ | | | √ | √ | | | √ | | |
| 40 | - | | | | | | | | | √ | √ | | | | | | | √ | √ | | | √ | | |
| Total | - | 3 | 7 | 7 | 0 | 7 | 1 | 5 | 0 | 5 | 12 | 4 | 1 | 0 | 5 | 0 | 0 | 16 | 5 | 3 | 4 | 17 | 1 | 3 |

**Table 4.2: Crops grown by interviewees from the western villages.** The table outlines the crops commonly grown by each of the 19 interviewees from the western villages. Plot size could not be included as the farmers were not familiar with the size of their fields.

A local non-governmental organization (NGO), the Association for Water and Rural Development (AWARD), was present in Motlamogatsane, working with the farmers, in the period 2004 to 2009. The NGO had four participatory projects in the village, one that worked to limit erosion in the wetland and to help improve farming mechanisms, one that worked to limit erosion in the upland, a governance project and finally a project on intensive food security, where the farmers were encouraged and taught how to start backyard vegetable gardens. The work done by AWARD provided a good research opportunity, looking at how external input has influenced the farmers' ability to cope and adapt to climatic variability and extreme weather events.

## 4.5 Bringing together qualitative and quantitative data

The derivation of data can happen through quantification of the phenomena, resulting in quantitative data, or through a structure that represents some characteristic of the phenomena, resulting in qualitative data (Valsiner, 2000). In the 1980s there were debates around whether the one approach is superior or more suitable than the other in vulnerability and poverty research (Marsland et al., 2001; Ziervogel et al., 2006b). This debate turned in the 1990s to looking at how quantitative and qualitative approaches can complement each other, and it has been argued that a mixed method approach to the collection and analysis of data can yield more trustworthy information than when the methods are used separately (Marsland et al., 2001). As was recently argued by Osbahr et al. (2010), combining quantitative and qualitative methods is important as it works to challenge the somewhat subjective and soft data associated with qualitative analyses, and the validity of quantitative data. While quantitative research works to ensure representativeness and reliability, qualitative research works to ensure that the appropriate questions are asked, that the actual situation on the ground is taken into account and that the results are interpreted accurately (Parker and Kozel, 2004). The one method thus complements the other, ensuring that the analysis gives as full and comprehensive a picture as possible of the research phenomena.

This research with small-scale farmers in the Bushbuckridge area has combined analysis of qualitative climate data with analysis of qualitative data from questionnaires and focus groups. For the latter, a combination of narrative and structured analysis has been applied in order to create a rich and contextual understanding of farmers' situation in Bushbuckridge. The table below outlines the data sources that worked to inform the different analytical aspects of the research.

| Chapter | Analytical aspect | Data source |
|---|---|---|
| **5.1 Perceptions and historical records** | Establish farmers' perceptions of the nature of different climatic variables (stressors). | Questionnaires |
| | Explore how perceptions of different climatic variables differ between the eastern and the western villages. | Questionnaires |
| | Outline historical nature of the climatic variables (stressors). | Historical climate data from local stations |
| **5.2 Vulnerability** | Explore the main problems the farmers face in everyday life. | Questionnaires/ Focus groups |
| | Explore the sensitivity and resilience indicators of vulnerability in order to assess the difference in vulnerability between the eastern and western villages. | Questionnaires |
| | Establish the exposure indicators of vulnerability. | Historical climate data from local stations |
| | Contextualise the vulnerability of farmers by going beyond the indicators, trying to; understand *why* the villages have high or low scores for the different indicators; understand *why* the villages differ; and to uncover some of the *barriers* to adaptation. | Questionnaires/ Focus groups |
| **5.3 Coping** | Establish the number of farmers practicing each of the different coping and adaptation mechanisms. | Questionnaires/ Focus groups |
| | Establish the difference between the villages and the commonality of the different coping and adaptation mechanisms. | Questionnaires/ Focus groups |
| | Explore why the farmers practice or don't practice the different coping and adaptation mechanisms. | Questionnaires/ Focus groups |
| **5.4 Future Projections** | Outline the direction of change of a range of climatic variables into the future. | Downscaled climate change projections |

**Table 4.3: Analytical aspect**

## 4.6 Structured interviews

The initial set of data was collected through one-on-one, structured interviews with a total of 42 farmers (n=42) across the four villages, Motlamogatsane (n=9), Phelandaba (n=10), New Forest (n=12) and Dingleydale (n=11). While the farmers interviewed in Motlamogatsane, Phelandaba and Dingleydale speak Sotho, the farmers in New Forest speak Shangaan. The interviews were conducted by the researcher together with an experienced translator, who speaks both Shangaan and Sotho, and the answers were transcribed in English by the researcher.

**Developing the questionnaires**

The structured questionnaires (see appendix A) had a mix of open-ended and closed questions. The first questionnaire draft, structured to uncover general information and specific information towards the research objectives, was reviewed by two contacts from the wider research area who have experience of working with small-scale farmers, and the draft was then edited accordingly. The second draft was used for the first day of interviews, after which it was reviewed by the researcher, following the experiences from the first interviews.[9] This final draft was then used throughout the rest of the interviews.

**Sampling**

A relatively equal number of interviews were conducted in the eastern and the western villages, in order to make comparisons between the eastern and the western villages. The only requirement from the interviewees was that they carry out some form of farming activity. The majority of interviews in the eastern villages, New Forest and Dingleydale, were organised through the chairperson of each of the irrigation schemes, who invited farmers in the schemes to participate. A small number of interviewees were also contacted in the fields by the researcher. In the one western village, Motlamogatsane, the majority of the interviewees were contacted through the translator, who had been working in the village with AWARD,[10] while a few were contacted at random in their homestead or in their field. In the other western village, Phelandaba, all the interviewees were contacted at random in their homestead.

[9] The changes that were made after the first day of interviews were so small that the initial interviews could still be used for data analysis.
[10] See section 4.2 about the study area for more information on AWARD.

## 4.7 Focus group discussions

Focus group discussions were conducted about two months after the interviews, bringing together as many as possible of the interviewees. In the eastern villages the focus group discussion were conducted at irrigation scheme offices, while in the western villages they took place in participants' homes. As with the interviews, the discussions were conducted by the researcher and the same translator, and transcribed (in English) and recorded with an audio recorder.

### Planning the focus group discussions

The focus groups worked to clarify some of the issues that came up during the interviews and to confirm some of the initial findings, while also focusing on a new section (thresholds). In planning the focus group discussions it was important to choose whether there was to be a structured or unstructured approach. Given the desire to go through quite specific issues and themes a structured approach with relatively high moderator intervention was chosen. Detailed outlines were therefore prepared, based on information from the interviews and on the research objectives. Because of some differences between the villages that became apparent in the interviews, the outlines were slightly different for the four different villages (for full focus group discussion outlines see appendix B).

### Conducting the focus group discussions

Eight focus group discussions were conducted, two in Motlamogatsane, one in Phelandaba, three in New Forest and two in Dingleydale, with the number of participants in each ranging from two to five. Overall 26 out of the 42 farmers interviewed attended the focus groups.

## 4.8 Individual, unstructured interviews

In addition to the interviews and focus groups with the farmers, three interviews with different officials working with farmers were conducted in order to get a more external overview and perspective of the context within which farmers in Bushbuckridge work. Two extension officers were therefore interviewed from the eastern villages, as well as an officer working with MABEDI[11] the last four years. These interviews were unstructured, only guided by a set of themes, and

[11] See section 4.2 about the study area for more information on MABEDI.

the qualitative information collected has complemented the analysis where appropriate.

Farmers from the western villages reported that they have not had any contact with extension officers, and the only external overview and perspective available was through the translator, who has been working with AWARD in Motlamogatsane. While no official interview took place, information gathered through discussions and interaction with the translator has worked to inform the research.

## 4.9 Climate Data

Historical climate data was used in the research in order to get an understanding of the climatic trends in the area over the last 30 years, while climate change projections were used to get an understanding of what the future climate is likely to look like. Aiming to get a local perspective it was important to use local historical station data as well as locally downscaled climate change projections.

### Choice of stations

Lack of the necessary, reliable meteorological data is a recognised phenomenon (Ziervogel and Ziermoglio, 2009), especially in remote rural areas in Africa (Speranza, 2010). As expected, it was thus a challenge to locate a sufficient number of climate data stations within the study area. One station with adequate rainfall data was located in the actual research area, in the village of New Forest. For temperatures there were no stations in the Bushbuckridge Local Municipality with sufficient records for historical analysis or for production of downscaled projections. Therefore, the two stations with sufficient temperature data in the closest proximity to the research area had to be chosen. These two stations, Pretoriuskop and Skukuza, have provided the basis for the analysis of historical trends and future projections of temperatures, while for precipitation it was also possible to include the station within the research area, New Forest. Below is a map with the location of the stations, as well a table with details of the location and time series available at each of the three stations. While the one station, New Forest, is located in the one eastern village, the other stations are located south of the study area. Skukuza is approximately 70 km from the western villages and 55 km from the Eastern villages, while Pretoriuskop is approximately 60 km from the Western villages and 50 km from the Eastern villages.

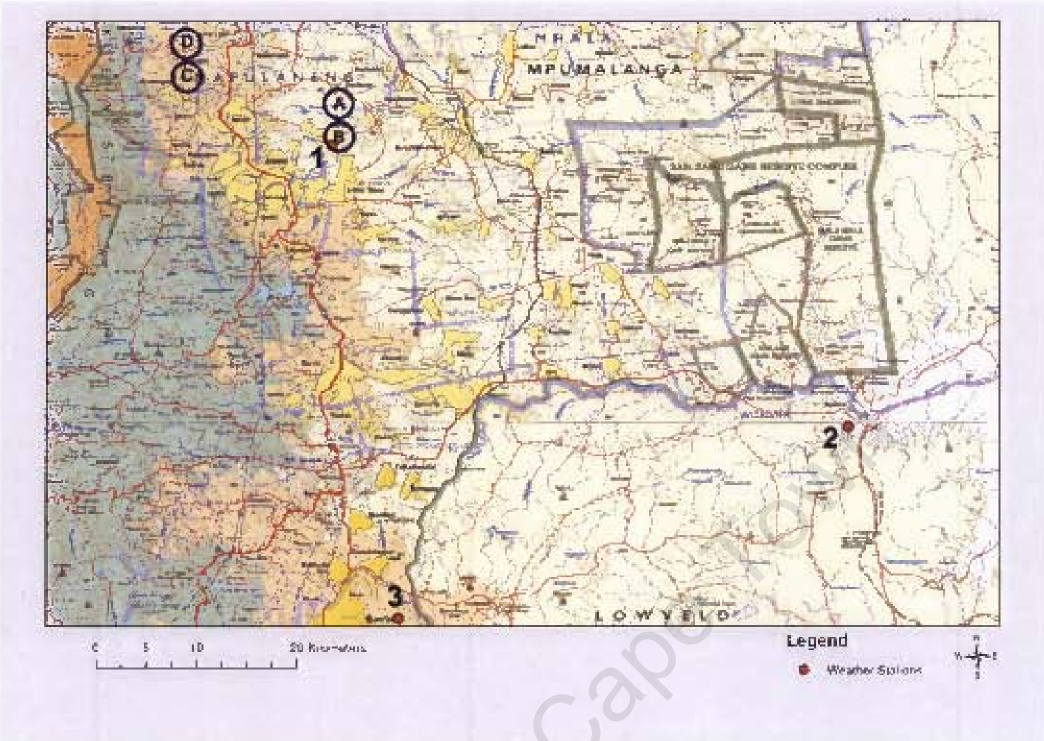


**Figure 4.7: The location of the weather stations in relation to study villages.**
Weather stations: 1) New Forest, 2) Skukuza, 3) Pretoriuskop
Villages: A) Dingleydale, B) New Forest, C) Phelandaba, D) Motlamogatsane
(Source: GIS maps, using National Geo-spatial information, Department of Rural Development and Land Reform)



| Name (station number) | Location | Altitude | Variables Available | Time series available |
|---|---|---|---|---|
| **New Forest (Bosbokrand)** (0595195_4) | 24.75° lat, 31.12° long | 609 m | Rainfall | 01.01.1950 - 29.02.1996 |
| **Pretoriuskop** (0556460_W) | 25.17° lat, 31.18° long | 573 m | Rainfall | 01.11.1938 – 31.07.2000 |
| | | | Temperature | 01.01.1960 – 31.12.1999 |
| **Skukuza** (0596179_W) | 25.0° lat, 31.58° long | 274 m | Rainfall | 01.09.1911 – 31.03.2010 |
| | | | Temperature | 01.01.1960 – 29.02.2000 |

**Table 4.4: Location and altitude of local stations and data availability**

While the table above outlines the time periods for which data is available, it is important to note that there is data missing within those time periods. An outline of the extent of the missing data can be found in appendix C.

When using three different stations as a basis it is important to have some basic understanding of the differences between the three. The table below therefore outlines some basic statistics from the different stations' records. A few aspects should be noted when the data from the different stations is used for analysis. First, the weather station at Skukuza, which is based at the lowest altitude, 274 meters above sea level, has an average maximum temperature that is two degrees higher than that of Pretoriuskop, which is based at 573 meters above sea level. It can be deduced that the temperatures at New Forest would be closest to those at Pretoriuskop, as New Forest weather station is based at 609 meters above sea level. Second, there is quite a lot of difference between stations in the mean annual rainfall, with New Forest experiencing almost 300 mm more rain a year than Skukuza. These differences should be kept in mind throughout analysis, with a focus being more on trends and changes than actual quantities. At the same time the stations, while not all within the Bushbuckridge area, reflect how there can be climatic differences within a relatively small area. This implies that farmers living within the same municipality can face somewhat different climatic challenges.

| | New Forest | Pretoriuskop | Skukuza |
|---|---|---|---|
| **Mean annual rainfall (mm) (1960-1995)** | 857 | 701 | 553 |
| **Mean annual number of wet days (days >0,2 mm) (1960-1995)** | 100 | 69 | 65 |
| **Mean annual maximum temperatures (Deg C) (1960-1999)** | - | 27,5 | 29,6 |
| **Mean annual minimum temperatures (Deg C) (1960-1999)** | - | 14,9 | 14,5 |

**Table 4.5 Overview climatic variables at New Forest, Pretoriuskop and Skukuza**

## Climate change projections

Global Circulation Models (GCMs) form the basis for climate change projections by simulating the global climate system. Downscaling is used in order to provide information below the grid scale of GCMs, which is typically 3° x 3°. The climate change projections presented in this research are based on statistical empirical downscaling (down to the scale of individual stations), which couples local historical climate data with GCM outputs, using the quantitative relationships between local variations and the state of the larger scale climatic environment (Ziervogel and Ziermoglio, 2009). The climate change projections used for this research were provided by the Climate Systems Analysis Group (CSAG) through their Climate Information Portal (http://cip.csag.uct.ac.za/).

The projections used for the study of local climate change projections in the Bushbuckridge area include downscaling of multiple GCMs for each of the three weather stations analysed (see appendix D for a list of the GCMs used). The inclusion of multiple GCMs is necessary in order to account for the fact that climate models do not produce the exact same predictions. Different models have different parameterisations, approximations of processes that occur at scales that the GCMs cannot resolve numerically, and their skill in simulating different regions vary. Assuming that all models represent an equally likely response, it is thus necessary to consider an envelope of projections, thereby representing the range of responses produced by the different GCMs and thus the degree to which GCMs agree or disagree.

The projections consider two future time periods, the near future (2046-2065) and the distant future (2081-2100), as compared to the control period (1979-2000). The modelling for the control period is forced by observed greenhouse gas concentrations, and thus represents the observed climate period.

The modelling for the two future periods are forced by what is referred to as the A2 emission scenario. It represents a 'business as usual' future, where the world has consolidated into a number of economic regions in which there is emphasis on resource self-reliance. Accordingly, technological change is heterogeneous, with resource rich regions evolving resource-intensive economies (IPCC, 2000).

This scenario projects a medium to high emission trajectory, with cumulative carbon dioxide emissions in the period 1990 to 2100 set to approximately 1450 to 1800 Giga tonnes of Carbon (GtC) (IPCC, 2000).

The research focused on the one emission scenario only, A2, as the scope of the study, which includes analysis of both climate and social data, made it necessary to limit the extent of climate data analysis. The complexity of analysing a range of scenarios was thus not plausible in the context of this research. The choice was made on the A2 emission scenario because, given the current circumstances, the researcher finds this to be the most plausible scenario and because it provides the scenario with the clearest signals of change.

## 4.10 Data analysis process

### 4.10.1 Perceptions and historical records

The purpose of this section is to get an understanding of the historical nature of the main climatic stressors, the climatic factors that are giving farmers stress, and to investigate how historical records corresponds with farmers' perceptions. It focuses on the three main climatic stressors that farmers in Bushbuckridge were found to be coping with and adapting to.[12] The data analysis used information from the questionnaires to establish farmers' perception of the climatic stressors, and historical climate data from the three stations outlined in section 4.9 to understand the historical nature of the climatic stressors.

**Perceptions**

For the analysis of farmers' perception of the nature of the climatic stressors, of specific events, of how they vary from year to year and of whether they have changed, the following selected questions were included in the questionnaire:

1.39 Can you remember any extreme weather events that impacted your crops?
1.53 Does the general weather vary from year to year? How?
1.55 When does the rainy season start? Is this how it has always been?
1.57 Has the weather pattern somehow changed over the years you have been farming? How has it changed?

[12] Section 4.10.3 will explain how these three stressors were identified.

**Historical records**

When analysing the historical records the aim was to understand aspects of the current climate, focusing on the three climatic variables: late onset of the summer rainfall; heavy rainfall events; and high temperature events. It was further aimed at getting an understanding of how the historical records correspond with the farmers' perception of extreme events, climate variability and change.

*Late onset of the summer rainfall*

The timing of the onset was identified using a standard set by the United States Agency for International Development's Famine Early Warning System (FEWS), where the rainy season is said to have started if there is 25 mm of rain over ten days, followed by a minimum of 20 mm of rain over the next 20 days (AGRHYMET, 1996). This definition made it possible to determine the timing of the onset using daily historical records from the three stations, New Forest, Pretoriuskop and Skukuza.

Three aspects of the onset were analysed, namely the specific days and months in which the onset has started each year over the time-period available in the historical data, changes over time in the timing of the onset and variability in the timing of the onset from year to year:

- *The timing of the onset* was analysed through identification of the month in which the rain had started each year at each station using the standard set by FEWS. This further made it possible to identify the month(s) in which the rain usually starts. The timing of the onset was further analysed looking at the mean, standard deviation and median of the day of onset.

- *Changes in the timing of the onset over time* were analysed, detecting statistically significant trends using the Mann-Kendall test and the nptrend test. These tests were chosen due to the non-parametric nature of the data, and two different tests were used in order to create robust results. The nptrend test was conducted in the programme Stata Statistical Software: Release 11, while the Mann-Kendall was conducted using Makesens 1.0 MSExcel template developed by the Finnish

Meteorological Institute. For both tests, p-values greater than 0,05 reflect statistically significant trends.

- *Variability in the timing of the onset* was analysed comparing the range of months in which the rain was found to start in the period between 1960 and 1995.

*Heavy rainfall*

Heavy rainfall events were defined as being events where there had been a minimum 100 mm of rainfall over a three-day period. This heavy rainfall threshold established for the Bushbuckridge area is partly based on experience and partly on literature. Firstly, experience from the field indicates that 100 mm of rainfall within 24 hours can cause quite significant flooding and erosion. Secondly, as the accumulation of rainfall over several days can cause flooding, one should focus on more than one day. Higgins et al. (2000), for example, look at three days of accumulated rainfall in their study of extreme precipitation events in the western United States.



Three aspects of the rainfall were analysed, namely the number of heavy rainfall events, rainfall changes over time and rainfall variability:

- *Heavy rainfall events* were identified through the identification of events where historical data showed a minimum of 100 mm of rainfall over a period of three days at at least one of the stations.

- *Rainfall changes over time* were analysed, detecting statistically significant trends using the Mann-Kendall test and the nptrend test. These tests were chosen due to the non-parametric nature of the data, and two different tests were used in order to create robust results. The nptrend test was conducted in the programme Stata Statistical Software: Release 11, while the Mann-Kendall was conducted using Makesens 1.0 MSExcel template developed by the Finnish Meteorological Institute. For both tests, p-values greater than 0,05 reflect statistically significant trends.

- *Rainfall variability* was analysed using the percentage standard deviation of the monthly rainfall recorded over the period 1960 to 1995. The percentage standard deviation was used in order to make the rainfall variability at the three stations, which have slightly different magnitudes of rainfall, comparable.

*High temperatures*

As outlined in section 4.9 above, temperature data was only available from two of the stations, namely Pretoriuskop and Skukuza. High temperatures were investigated by analysis of whether extreme temperature events recalled by the farmers could be identified in the historical data, of changes in temperatures over time and of temperature variability:

- *Extreme temperature events* were analysed by comparing the mean monthly minimum and maximum temperatures of a year that, according to the farmers' recollections, had extreme temperatures, with the average monthly temperatures for that decade.
- *Changes in temperatures over time* were analysed, detecting statistically significant trends using the Mann-Kendall test and the nptrend test. These tests were chosen due to the non-parametric nature of the data, and two different tests were used in order to create robust results. The nptrend test was conducted in the programme Stata Statistical Software: Release 11, while the Mann-Kendall was conducted using Makesens 1.0 MSExcel template developed by the Finnish Meteorological Institute. For both tests, p-values greater than 0,05 reflect statistically significant trends.
- *Temperature variability* was analysed using the standard deviation of the mean monthly minimum and maximum temperatures recorded over the period 1960 to 1999.

### 4.10.2 The vulnerability of small-scale farmers in Bushbuckridge

The purpose of this section is to assess the vulnerability of small-scale farmers in Bushbuckridge. This entails discovering the problems that the farmers face in everyday life, as well as an assessment of their differential vulnerability to climate variability and extreme weather events. The sections thus has two parts, the first being an analysis of the main problems, and thus the non-climatic stress factors which farmers are dealing with, and the second being an analysis of the farmers differential vulnerability using an indicator approach.

**Vulnerability to non-climatic factors**

The main problems were identified through the following question in the questionnaire:

> 1.63 What do you find are the main problems you face as a farmer? Why?

The focus group discussions then worked to confirm or challenge those problems that were identified in the questionnaires, and to get a better understanding of the problems. This was done in section three in the discussions (for full focus group discussion outlines see appendix B), where props were used to represent the different problems that had been identified, and the farmers were asked to place a rock(s) next to the prop(s) that they see as representing the biggest problem(s). Discussion was then initiated around why these are the biggest problems, and towards gaining understanding of new problems, if such had arisen. The focus in the different discussion groups was on the biggest problems that were identified in that village, and so differed from village to village.

**Differential vulnerability to climate variability and extreme weather events**

The vulnerability analysis was aimed at creating an understanding of the farmers' current vulnerability to climate variability and extreme events, more specifically so to understand whether there is any difference between the vulnerability of the farmers from the eastern and the western villages. This was done by combining structured analysis of qualitative data, in the form of vulnerability indicators, and narrative analysis, by including more soft data from interviews and focus groups. The data for the vulnerability indicators was collected through specific questions in the questionnaires.

*Vulnerability indicators*

Indicators for analysing the vulnerability of farmers in Bushbuckridge were chosen based on analysis of various literature, and were framed within the three categories outlined by the Turner et al. (2003a) framework, exposure, sensitivity and resilience. The sections below give an outline of the different indicators that were chosen, why and how they were used. It is important to note that while the indicators have been divided into these three categories, there are some indicators that do not fit exclusively into one category. While still allocated to specific categories, those indicators that can be seen as reflecting more than one category are highlighted below.

*Exposure*

The analysis focuses on Bushbuckridge farmers' exposure to climatic factors only, more specifically on indicators of climate variability and extreme weather events. Non-climatic stress has instead been discussed qualitatively in the section that contextualises the main problems that farmers are facing.

The indicators of exposure do not address differences between the eastern and the western villages, as it was not been possible to access different site-specific historical climate data from the two areas. The exposure of farmers in Bushbuckridge to climate variability and extreme weather events was therefore analysed by looking at the exposure of the area as a whole. Table 4.6 below gives an overview of the indicators that were used.

| | Exposure | | | |
|---|---|---|---|---|
| **Indicator** | **Description of indicator** | **Why it should be an indicator of exposure to climate variability and extreme weather events** | **How the indicator is analysed** | **Hypothesised functional relationship between indicator and vulnerability** |
| Heavy rainfall events | Frequency of heavy rainfall events in the period 1960-1995. | Heavy rainfall can cause erosion and crop degradation, damaging fields and agricultural yields. | Analysed looking at the number of rainfall events with over 100 mm, between 100 and 150 mm or over 200 mm of rainfall over a three-day period. | The higher the frequency of events, the higher the vulnerability. |
| Droughts | Frequency of droughts in the period 1960-1995. | Droughts make agricultural activities difficult, drying up soil, river and dams, sometimes dehydrating and killing crops. | Analysed using three-month periods in the rainy season, September-May, detecting the periods where rainfall values fall within the 20th percentile, so are exceptionally low, while at the same time average temperatures fall outside the 80th percentile, so are exceptionally high. | The higher the frequency of events, the higher the vulnerability. |
| Variability in the timing of the onset | How much the timing of the onset varies in the time period 1960 to 1995. | Variability in the timing of the onset makes it difficult to plan agricultural activities, especially for farmers without irrigation. | The onset was determined using the definition of 25 mm of rain over ten days, followed by a minimum of 20 mm of rain over the next 20 days.[13] Analysed looking at both the variability of the month of onset and the mean, standard deviation and median of the day of onset. | The greater the variability the greater the vulnerability. |
| Rainfall variability | Variability in the mean monthly and annual rainfall (mm) in the period 1960 to 1995. | The mean monthly and annual rainfall plays an important role for water availability, and the variability affects farmers' ability to plan and follow routines - the more difference from year to year and month to month the harder it is to plan and farm consistently. | Analysed looking at the percentage standard deviation of the mean monthly and annual rainfall. | The greater the variability the greater the vulnerability. |
| Temperature variability | Variability in mean monthly maximum and minimum temperatures in the period 1960 to 1999. | The monthly temperatures are important as it reflects the conditions that farmers have to deal with from year to year – the more difference from year to year the harder it is to plan and farm consistently. | Analysed looking at the percentage standard deviation of the monthly mean for minimum and maximum temperatures. | The greater the variability the greater the vulnerability. |

**Table 4.6: Indicators of exposure to climate variability and extreme weather events**



[13] As is the FEWS definition outlined in section 4.10.1

*Sensitivity*

The sensitivity of the farmers in Bushbuckridge was analysed through the comparison between the sensitivity of the farmers from the eastern and the western villages, using the indicators outlined in the table below.

| **Sensitivity** | | | |
|---|---|---|---|
| **Indicator** | **Description** | **Why it should be an indicator of sensitivity to climate variability and extreme weather events** | **Hypothesised functional relationship between indicator and vulnerability** |
| Irrigation | Proportion of farmers that have irrigation. | Areas of non-irrigated cropland are more prone to be impacted by drought than irrigated cropland (Wilhelmi and Wilhite, 2002; O'Brien et al., 2004b). | The farmers who have irrigation are less sensitive than the farmers without irrigation. |
| Education (out of 30)[14] | Proportion of households that have one or more members who have completed primary education, Grade 7. | Education makes one better equipped to negotiate fair solutions (Adger et al., 2004), can improve ones ability to adopt more modern farm technology (Benhin, 2006) and being able to read makes it easier to receive training (Machethe et al., 2004). | The farmers with households where one or more person has completed primary education are less sensitive than farmers without education. |
| Crop damage from extreme events[15] | Proportion of farmers who mentioned one or more events where they had lost some, a lot or all of their crops. | Destruction of assets and the loss of income reduce the ability to recover after an extreme event (Kaplan et al., 2009). | The farmers who have lost some, a lot or all their crops because of one or more extreme weather events are more sensitive than those who have not. |

**Table 4.7: Indicators of sensitivity to climate variability and extreme weather events**

*Resilience*

Resilience is concerned with a system's ability to cope or respond to disturbances acting from both within and beyond the system (Turner et al., 2003a). The resilience of the farmers in Bushbuckridge was analysed through the comparison between the resilience of the farmers in the eastern and the western villages, using the indicators outlined in the table below.

[14] In the case of education only 16 of the farmers in the eastern villages and 14 of the farmers in the western villages provided answers that could be used for analysis.
[15] Though analysed here as a indicator of sensitivity, crop damage from extreme events does also reflect the degree to which a farmer is exposed to extreme events, as his crop damage will also be shaped by the degree to which he is exposed to extreme events.

| Resilience | | | |
|---|---|---|---|
| **Indicator** | **Description** | **Why it should be an indicator of sensitivity to climate variability and extreme weather events** | **Hypothesised functional relationship between indicator and vulnerability** |
| Off-farm employment | Proportion of households that have one or more family member with off-farm employment | Access to off-farm employment is one of the most common indicators of food security (Kasperson et al., 2005), and is a way by which farmers can diversify their income, be more resilient, and less vulnerable to failed harvests (O'Brien et al., 2004b). | The farmers with one or more household members with off-farm employment are more resilient and thus less vulnerable than those who do not. |
| Government support | Proportion of the households receive monthly government grants | Receiving government grants is commonly recognised as a way to increase resilience (O'Brien et al., 2004b; Kaspersen et al., 2005; Kaplan et al., 2009). | The farmers from households receiving government support are more resilient and thus less vulnerable than those who do not. |
| Support from friends/ family | Proportion of farmers receiving some form of support from family or friends not currently living in the household | Borrowing food or eating elsewhere has been recognised as a common, short term, coping strategy in Sekhukhune, Limpopo (Ziervogel et al., 2006b), and such support from friends and family has been recognised as a social capital (Kaplan et al., 2009), which in turn can be seen as increasing the ability to cope with and adapt to climate variability and extreme weather. | The farmers with households receiving support from friends and family are more resilient and thus less vulnerable than those who do not. |
| Access to agricultural insurance | Proportion of the farmers who have agricultural insurance | Insurance works to spread the risk of loss over a wide population base, over many years (Patt et al., 2010). Buying insurance has been recognised as a common adaptation option for the volatile agricultural sector (Risbey et al., 1999; Smit and Skinner, 2002; Benhin, 2006; Smit and Wandel, 2006). | The farmers who have agricultural insurance are more resilient and thus less vulnerable than those who do not. |
| Access to credit | Proportion of the farmers who have borrowed money | Access to credit can increase the resilience of farmers (Ghetibouo and Ringler, 2009). The absence of access to credit is a critical problem for smallholder farmers (Machethe et al., 2004). | The farmers who have accessed credit are more resilient and thus less vulnerable than those who have not. |
| Membership in farm organisations | Proportion of the farmers that are members of farmer organisations | Membership in farm organisations has been recognised as positively influencing farmers' ability to adapt to change, thereby increasing their resilience (Ghetibouo and Ringler, 2009). Sharing experiences can help farmers identify gaps in their own ability to take on appropriate adaptation strategies, and make them able to reflect on experience and inform future actions (Archer et al., 2009). | The farmers who are members of farmer organisations are more resilient and thus less vulnerable than those who are not. |
| Crop diversification [16] | Proportion of the farmers growing four or more different crops | Crop diversification has been recognized as a common adaptation strategy, and is known to increase the resilience of farmers to climate variability and change (Ghetibouo and Ringler, 2009; Roncoli et al., 2002; Smit and Skinner, 2002; Ziervogel et al., 2006a). | The farmers who grow four or more different crops are more resilient and thus less vulnerable than those who do not. |

**Table 4.8: Indicators of resilience to climate variability and extreme weather events**

[16] Though analysed here as an indicator of resilience, crop diversification does also reflect sensitivity, in the sense that crops with different climatic requirements may be affected differently by the same climate.

#### 4.10.3 Coping with and adapting to climatic stress

The purpose of this section was to analyse the mechanisms by which farmers in the Bushbuckridge area are coping with, and adapting to, climatic stressors. This entailed integration of data from both the questionnaires and the focus group discussions. The analysis consists of three main components, namely:

1) Identification of the three main climatic stressors that the farmers are responding to, through the identification of strategies for coping with and adapting to climatic stress

The questionnaire was the initial way by which coping and adaptation strategies were identified. The following questions were designed to tease out the farmers' responses to stressors:

> 1.40 Have you found any ways to deal with the extreme events above?
>
> 1.52 How does the weather affect your farming decisions?
>
> 1.53 Does the general weather vary from year to year? How?
>
> 1.54 Do these variations in weather from year to year impact your farming activities? How?
>
> 1.57 Has the weather pattern somehow changed over the years you have been farming?
>
> *If yes*
>
> 1.571 How has it changed?
>
> 1.572 How has this affected your farming practices?
>
> 1.61 Have you changed practices/strategies on the farm since you started farming years? If yes, how, and what were these changes a response to?

The answers to these questions were all brought together to identify strategies used by farmers to deal with stress, and further made it possible to identify the most common stressors triggering the coping and adaptation strategies. The findings yielded 60 different cases of coping and adaptation, from which the three main triggers could be identified.

Having identified a number of coping and adaptation strategies, as well as the main climatic stressors that the farmers are responding to, the focus group discussions then worked to confirm the commonality of the different strategies and to create more information around each of the strategies. This was achieved by telling a fictional story related to one or two of the main climatic stressors identified as most common in that village. The participants were then asked what they would do in order to deal with that type of stress or incident, and this brought out new strategies, as well as confirming coping and adaptation strategies that came out in the questionnaires. Discussion was then encouraged to get further understanding of the different strategies.

2) Identification of impacts caused by the climatic stressors

The following questions from the questionnaire brought about some understanding of how climatic stressors are impacting crops and farming activities:

1.39 Can you remember any extreme weather events that impacted your crops?
1.54 Do these variations in weather from year to year impact your farming activities? How?

These questions, together with general information that came up sporadically through the rest of the questionnaire and through the focus group discussions, were used to create a picture of the different impacts that farmers are dealing with.

3) Investigation of potential coping and adaptation thresholds

The investigation of potential coping and adaptation thresholds was done through the focus group discussions. This was done following discussions around the different coping and adaptation strategies, after which the discussion was led towards the point beyond which the participants find themselves incapable of dealing with the climatic stressors. Because of the different nature of the stressors and their response mechanisms, the approach to the threshold discussions differed a lot between the three. More specifically, the approaches were as follows:

- *Late onset of the summer rainfall*: The point beyond which farmers can no longer delay their farming activities, such as ploughing and planting, while waiting for the rain to start.

- *Heavy rainfall events:* How much rainfall the fields are able to deal with before erosion and degradation takes place and the farmers are unable to farm as they usually do.

- *High temperatures:* The temperatures beyond which the farmers are unable to protect their crops.

For late onset of summer rainfall an additional method was developed following the first focus group discussions. The participants were engaged in an exercise were the names of the different months of the year were laid out on the floor, and they were given a set of cards each holding the name of a crop commonly grown in the area. As a group they were then asked to place the cards on the month for which it is best to plant that specific crop, and discussion was then facilitated towards the time beyond which it is no longer possible to grow the specific crops. This made it easier to get an understanding of the different conditions required by the different crops, as well as a planting time beyond which the crops no longer produce a sufficient yield.

### 4.10.4 Future projections

The purpose of this section was to assess downscaled climate change projections for the Bushbuckridge area. This was done using local climate change projections, as outlined in section 4.9, and as summarised below:

- Downscaled climate change projections from the following stations:

  New Forest (only rainfall)
  Pretoriuskop (rainfall and temperature)
  Skukuza (rainfall and temperature)

- Time periods:

  Control (1979 – 2000)
  Near Future (2046-2065)
  Distant Future (2081-2100)

- Climate change scenario:

  A2 (Business as usual)

The table below outlines the different future climate variables that were investigated, why and how they were analysed.

| Climatic variables | Description | Purpose | Method | Analysis |
|---|---|---|---|---|
| Rainfall anomalies | Changes in mean monthly and annual rainfall | To investigate whether rainfall is projected to increase or decrease, as farmers, especially those without irrigation, depend on sufficient water for farming activities. | For each station, scenario A2: Calculated the monthly anomalies for each of the future periods in relation to the control period, for each model output. Then calculated the monthly median anomaly and the $90^{th}$ and $10^{th}$ percentile across all the model outputs, for both future scenarios. This made it possible to investigate the agreement of the models towards the direction of change, for each station and for each of the future periods under the A2 scenario. | Analysed the agreement among the different model outputs for the projected monthly and annual anomalies, comparing the near and distant future periods and the different stations. Investigated the direction of change, and the degree to which the different future periods and the different stations showed the same direction of change. |
| Rain-day anomalies | Changes in mean monthly number of days with 50 mm of rainfall or more | To investigate whether projections show changes in the number of heavy rainfall events, as heavy rainfall can cause erosion and crop degradation, damaging fields and agricultural yields. | Same as above | Same as above |
| Temperature anomalies | Changes in mean monthly and annual temperatures | To investigate whether temperatures are projected to increase or decrease, as crops and thus farming systems are sensitive to changes in temperature. | Same as above | Same as above |
| Extreme temperature day anomalies | Changes in the mean monthly number of days with 40 Degrees Celsius or above | To investigate whether projections show changes in the number of days with extreme temperatures, as crops were said to struggle with temperatures over 40 Degrees Celsius. | Same as above | Same as above |
| Rainfall variability | Changes in mean monthly and mean annual rainfall variability | To investigate whether rainfall variability is projected to increase or decrease, as the variability affects farmers' ability to plan and follow routines - the more difference in monthly or annual rainfall from year to year the harder it is to plan and farm consistently. | For each station, scenario A2: Compared the monthly and annual percentage standard deviation for the control period with the monthly and annual percentage standard deviation the near and the distant future periods, for each model output. The number of models for which the percentage standard deviation showed an increase or a decrease, when comparing the control with the near future or the control with the distant future, was then counted, for each station. | Analysed the agreement among the projected change in variability, comparing the near and future periods and the different stations. Investigated the direction of change (increased or decreased variability), and the degree to which the different future periods and the different stations showed the same direction of change. |
| Temperature variability | Changes in mean monthly temperature variability | To investigate whether temperature variability is projected to increase or decrease, as the variability affects farmers' ability to plan and plant certain crops - the more difference in mean monthly temperatures from year to year the harder it is to plan and farm consistently. | Same as above | Same as above |

**Table 4.9: Overview of why and how the different climatic variables are analysed**

## 4.11 Limitations

### Data collection in the field

The relatively short time (4 weeks) spent in the field, could have led to insufficient trust between the researcher and the respondents, potentially resulting in biased results. It also meant that there was not time for the researcher to spend extensive time on the farmers' plots, which means that it was not possible to detect coping and adaptation strategies which farmers themselves did not think to describe.

It is also possible that data has been lost in translation, or even misunderstood, due to the use of a translator, even though the translator had significant field experience and was a given a thorough introduction to the context of the research as well as to the questionnaire and the focus group outlines. Some things are still difficult to translate, as for example the difference between the climate and the weather. It should also be noted that while the translator could speak both Shangaan and Sotho, she was more fluent in Sotho, which is her first language.

It should also be noted that the respondents to the questionnaires, and thus also the participants in the focus group discussions, do not necessarily represent a diverse group from the villages. This is due to the fact that the majority of the interviews in the eastern villages were organized through the chairperson of the irrigation schemes, meaning that they are farmers connected to the chairperson. In Motlamogatsane the majority of interviewees were farmers who had participated in the AWARD projects. Therefore, the majority of the farmers that were interviewed in New Forest, Dingleydale and Motlamogatsane could represent a group of farmers that have more contact networks and who are more progressive than the average.

Lastly, it should be noted that as there was no assessment made with regards to the population of the different villages, and the number of interviews made in relation to the population, it cannot be said whether the number of interviews that were made can be seen as representative of the different villages.

### *Climate data analysis*

The first limitation in the climate data lies in the limited availability of local climate data, both historical and downscaled projections. While rainfall data was available from one of the research villages (New Forest), as well as other locations in relatively close proximity, temperature data was only available from stations in more distant locations. This means that it was not possible to compare the eastern and the western villages. It also means that three stations, New Forest, Pretoriuskop and Skukuza, of which two are not in the research villages, had to be chosen to represent the historical climate and the climate change projections for the area.

The second limitation is related to the data missing within the historical data time series. When analysing the time periods 1960 to 1995, and 1960 to 1999, there are cases where more than 5% of the data is missing. While this does weaken the validity of the findings, no other applicable station data was available and the researcher had to make use of what was there.

The third limitation relates to the use of one rather than several climate change emission scenarios. By only presenting projections based on the A2, business as usual, emission scenario, the analysis does not represent a robust message that accounts for uncertainties related to the various emission paths the world might take.

The last limitation is that of the uncertainties inherent in climate modelling. While the use of multiple models and climate change projection envelopes works to represent the different uncertainties related to each GCM, it does not remove the element of uncertainty in its entirety. The use of downscaled climate change projections adds another layer of uncertainty in that they assume a stable cross-scale relationship in a perturbed climate. Furthermore, statistical empirical downscaling can sometimes lack coherency between the many climate variables, and is not able to accommodate regional feedbacks effectively (IPCC, 2007c).

# 5. Data analysis

## 5.1 Climatic Stressors – Perceptions and historical records

*Assessing the historical nature of the main climatic stressors, and how the historical records corresponds with farmers' perceptions*

This section takes a look into the nature of climatic stressors,[17] by comparing historical records with perceptions among farmers. It focuses on the three stressors that are identified as having triggered the most coping and adaptation strategies,[18] and takes into account some of the differences between the farmers from the western and eastern villages. Figure 5.1 below shows the different stressors, the number of adaptation and coping responses identified for each stressor as well as the total number of coping and adaptation cases.[19] Each farmer interviewed (n=42) gave one or more coping and adaptation responses.


**Figure 5.1: The climatic stressors triggering the most coping and adaptation strategies.** Based on interviews with 42 farmers, each of which could mention one or more coping and adaptation responses.

As can be seen in figure 5.1 above, late onset of summer rainfall is by far the most common stressor that the farmers are responding to, followed by heavy rain and high temperatures. Drought and low temperatures are less common, and lastly

[17] Stressors are factors that cause farmers stress.

[18] The way by which the coping and adaptation strategies were identified was outlined in the methodology.

[19] Note that the adaptation/coping cases do not necessarily refer to different types of responses, but just the number of cases where farmers outlined some form of response to deal with the stressor.

there are the other stressors that they are responding to, which include everything from wind to old age. While recognising that these latter factors cause farmers stress, they are not the focus of this analysis and will not be addressed further here.

### 5.1.1 Late onset of the summer rainfall

Late onset, a delay in the start of the summer rainfall (compared to the long term average onset date), was identified as the most common trigger for coping and adaptation strategies. While seven out of the coping and adaptation responses to late onset were made by farmers from the eastern villages, the majority, 17, were made by farmers from the western villages. This shows that, as one would presume, the late rain is a bigger problem among those without access to irrigation, than among those with irrigation. At the same time, it reflects how late onset can also be a problem for the irrigation farmers. As one of the irrigation farmers noted in the interviews, the soil is too dry if there is only irrigation.

#### Perceptions of when the rain starts

Looking at when the farmers believe that the rain usually starts gives an insight into how well they all agree on the timing of onset, which can then be compared with historical records. As can be observed in table 5.1 the perceptions vary a lot, from May to November. The majority of farmers can be found to believe that the rain usually starts in the interval August to October, but this is still quite a large spread. The large interval, three months, could be an indication of one or several of three factors, namely: that the time of the onset is slowly changing over the years, confusing the farmers; that the time of the onset varies very much from one year to the next; or that the farmers just don't really keep track of the months and when the rain starts. Very few farmers seem to be formally recording the time of the onset every year.

| | Rain starts → BUT ↓ | May/ June | July | Aug | Aug/ Sept | Sept | Sept/ Oct | Oct | Oct/ Nov | Different every year | Not sure | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Some form of change** | **Every year is different now** | | | 1 | 1 | | | | | | | 2 |
| | **Not anymore** | 1 | | 3 | | | | | | | | 4 |
| | **Has not started yet (late Sep)** | | 2 | 1 | 1 | 4 | | | | | | **8** |
| | **Starts later now** | | | 1 | 1 | 1 | | | | | | 3 |
| | **Used to start June/July** | | | | | 1 | | | | | | 1 |
| | **Used to start July/ August** | | | | | 1 | 2 | | | | | 3 |
| | **Sometimes earlier now** | | | | | | 1 | | | | | 1 |
| **No change/ comment** | **Hasn't changed** | | | | | 5 | 1 | 2 | | | | **8** |
| | **No comment** | | | 2 | 1 | 3 | | 1 | 1 | 1 | 2 | **11** |
| | SUM | 1 | 2 | **8** | 4 | **15** | 4 | 3 | 1 | | 2 | 41[20] |

**Table 5.1: Farmer's perception of when the summer rainfall starts (horizontal axis) and whether it has changed (vertical axis)**

As can be observed in table 5.1 above, 54% of the 41 farmers responded that there is some form of change, while 46% either had no comment or said that it had always been the same. A slight majority of farmers therefore feel that the timing of the onset has changed. The majority of those who believe that the timing of the onset has changed, 15 farmers, believe that the rain now starts later than it used to. It is important to notice though, that eight of these 15 base their statement on the fact that the rain had not yet arrived at the time of the interview (late September 2010). Other research has also found that farmers sometimes put more weight on information from recent events than is sensible (Maddison, 2006; Gbetibouo, 2009). For example, farmers have been found to base their planning on experience from recent years, rather than on the basis of climatic norms (Maddison, 2006).

The farmers were also asked about whether the weather usually varies from one year to the next (not included in table 5.1 above), so whether there is an inter-annual variability, and here 23 farmers, so 56%, responded that the timing of the

[20] There are only 41 here as one farmer's answer has been treated as an outlier.

onset varies. It therefore seems that perceptions among the farmers include both that the onset of the summer rainfall has been changing over the years, as well as that the timing of the onset varies one year to the next.

**Historical onset records – when does the rain really start?**

As the historical records for the three weather stations in table 5.2 show, the timing of the onset varies slightly between the different locations.[21] While in New Forest it is by far most common that the rain starts in October, the other two stations show a spread also towards November and even December. If considering all three stations combined though, October is by far the most common month for the onset of the summer rainfall. This does not correspond very well with perception among the majority of the farmers, who found that the rain usually starts around August and September. This is not to say that they were completely wrong though, as it does also happen occasionally that the rain starts in August and September.

The spread in the timing of the onset, as reflected in table 5.2, shows that the timing of the onset varies considerably. In order to test the validity of the variation, onset statistics are outlined in table 5.3. Looking at the statistical overview, it can be found that the timing of the onset has a standard deviation of between 44 and 50 days, if considering all three stations. This confirms that the timing of the onset is spread out over quite a wide range of dates. Because the mean can be skewed by outliers, it is also important to look at the median, as well as the 10$^{th}$ and 90$^{th}$ percentile. The median shifts the onset to about ten to fifteen days later for all three stations, reflecting how the mean has only been slightly skewed by a few very early onsets (probably the June onsets). The 10$^{th}$ and 90$^{th}$ percentile show that in New Forest the large majority of the onsets fall in the 123 days interval between July 20th and November 20$^{th}$. For Pretoriuskop

[21] Note that onset has been defined by the standard set by the United States Agency for International Development's Famine Early Warning System (FEWS), 25 mm of rain over ten days, followed by a minimum of 20 mm the next 20 days (AGRHYMET, 1996) (as outlined in the methodology). The difference between the different stations could be related to the fact that, on average, it rains more at New Forest than at the two other stations, and so the definition for the onset might potentially be better for detecting the onset at a location with around 850 mm of annual rainfall (New Forest), than at locations with 700 mm (Pretoriuskop) and 550 mm (Skukuza) of annual rainfall.

and Skukuza the large majority of the onsets fall in the 64 days interval September 13th and November 17th and the 90 days interval September 14th and December 13th respectively. These findings show that the farmers in Bushbuckridge experience a large variability in the timing of the onset of the summer rainfall. The large spread in the perceived timing of the onset (August – October if including only 35 of the 41 interviewees), can thus to some extent be explained by the fact that the time of the onset varies from one year to the next.

| | New Forest | Pretoriuskop | Skukuza | Combined |
|---|---|---|---|---|
| **June** | 3 | 2 | 2 | 7 |
| **July** | 1 | 1 | 1 | 3 |
| **August** | 2 | 0 | 0 | 2 |
| **September** | 4 | 4 | 4 | 12 |
| **October** | **18** | **12** | **9** | **39** |
| **November** | 3 | 12 | 9 | 24 |
| **December** | 3 | 2 | 9 | 14 |
| **January** | 0 | 1 | 0 | 1 |

**Table 5.2: Historical onset for New Forest, Pretoriuskop and Skukuza for the period 1960-1995,** showing the number of times that the onset has started in the different months at each station and at all the stations combined.

| | New Forest | Pretoriuskop | Skukuza |
|---|---|---|---|
| **Mean** | 02 October | 19 October | 26 October |
| **St. Dev.** | 49 days | 44 days | 50 days |
| | | | |
| **10th percentile** | 20 July | 13 September | 14 September |
| **Median** | 10 October | 30 October | 10 November |
| **90th percentile** | 20 November | 17 November | 13 December |

**Table 5.3: Onset statistics based on data in table 5.2**

In terms of changes in the onset with time there seems to be a slight shift towards a later onset at all stations, if considering the graphs in figure 5.2 below. This corresponds with the slight majority of the farmers, 54%, who believe that the timing of the onset has changed. Still, statistical testing, using both the Mann-Kendall test and the nptrend test, it was found that these trends are not statistically significant.

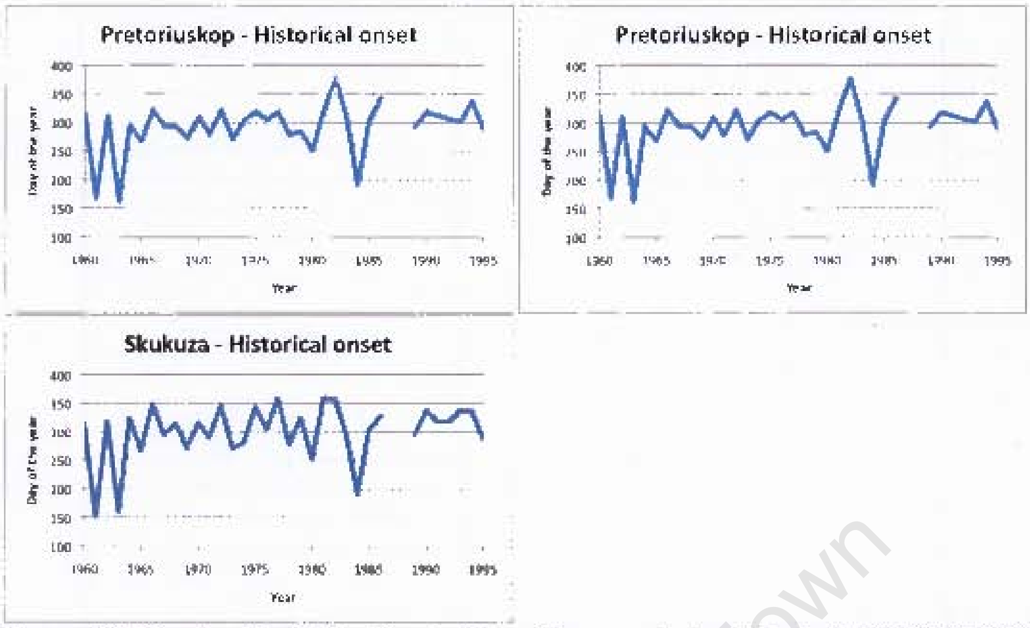


**Figure 5.2: Graphs displaying the timing of the onset over the period 1960 to 1995 at New Forest, Pretoriuskop and Skukuza**

#### How the perceptions and historical records correspond

The farmers' perception of when the rain usually starts was found to vary a lot from farmer to farmer, and was somewhat different from what was established from the historical climate records. This could be related to the large inter-annual variability in the timing of the onset. In the historical records it was found that while the rain most often starts around October, it commonly also starts in September, November and December. No significant trend could be established with regard to a change in the timing of the onset over time, and so the farmers' perception that the timing of the onset has changed could not be confirmed. So in the end, the variability in the timing of the onset, together with the fact that the farmers don't seem to keep any records of when the rain starts, can thus give some explanation as to why there was little consensus around when the summer rainfall usually starts.

### 5.1.2 Rainfall

Extreme rainfall is the second most common trigger for coping and adaptation strategies. This section will elaborate on heavy rainfall events, as well as some perceptions of general rainfall and records. Responses to heavy rainfall were mainly carried out by farmers from the western villages, with only one of the ten responses being made by a farmer from the eastern villages. This can potentially be linked to the location of the fields, as the farmers from the eastern villages are farming in the upland, while the farmers from the western villages all have fields down in the wetlands. So while on the one hand the wetland makes the farmers less prone to drought it can on the other hand make them more susceptible to heavy rainfall.

***Perceptions of rainfall***

The farmers seemed to find it difficult to remember the year that heavy rainfall events took place, and could only remember events from the last 12 years. Year 2000 was the most common year mentioned, which could be related to cyclone Eline, which was found to bring flooding to Mozambique and to parts of Limpopo (Thomas et al., 2007).

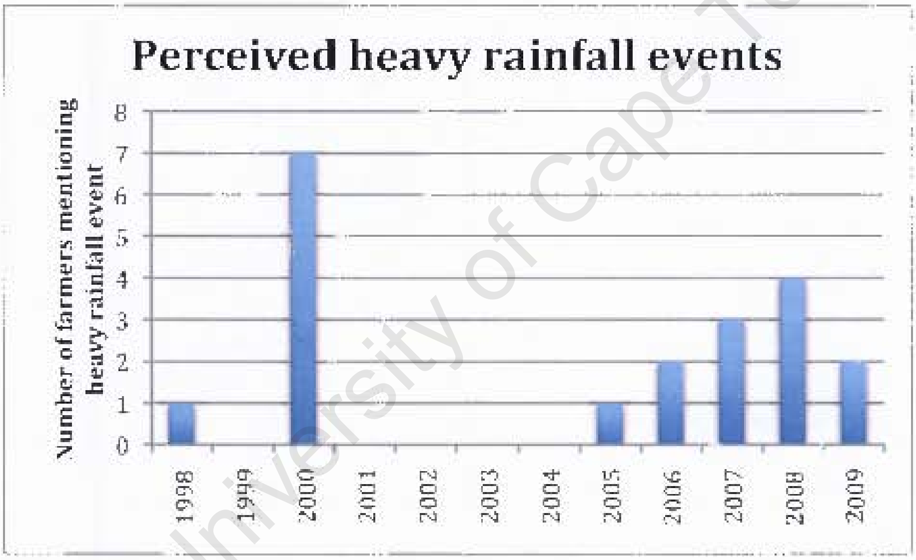


**Figure 5.3: Years of perceived heavy rainfall events**

The farmers were also asked whether they think the weather pattern has somehow changed over the time that they have been farming, and answers include:

- Rains less than it used to (14 interviewees).
- Changes in the way it rains - used to be good, light rain, while now the rain comes more seldom, and when it does come it is a heavy rain. (6 interviewees).

- The way it rains is different one year to the next (9 interviewees).

Some farmers also mentioned a light, post harvest rain (~ June) that would "clean" their fields, but which does not come anymore. Generally it was found that, while many of the farmers argued that it now rains less, a few also say that there have been changes in the way it rains, that there is now shorter, more heavy rain that causes flooding. What is more, farmers also argue that there is a general variability from year to year both in the way it rains and in how much it rains.

### Historical records

Extreme rainfall events were investigated by looking at events where it has rained 100 mm or more over a three-day period. Figure 5.4 shows the heavy rainfall events identified at each of the stations.[22] In order to get an understanding of the rainfall in a wider area the table shows the rainfall at both stations, even when only one station experienced over 100 mm of rainfall. As can be observed in the table below, heavy rainfall events were identified in two of the years that were mentioned by the farmers, namely 2000 and 2006. In 2006 there were actually three heavy rainfall events identified, but non of which actually took place at both stations, indicating that they were very localised events.



[22] The analysis only includes data from Pretoriuskop and Skukuza, as New Forest does not have any rainfall data for the period 1998 to 2009. For Pretoriuskop and Skukuza, there is only data up until 2006 and April 2010 respectively, and so the analysis only includes events up until April 2006.

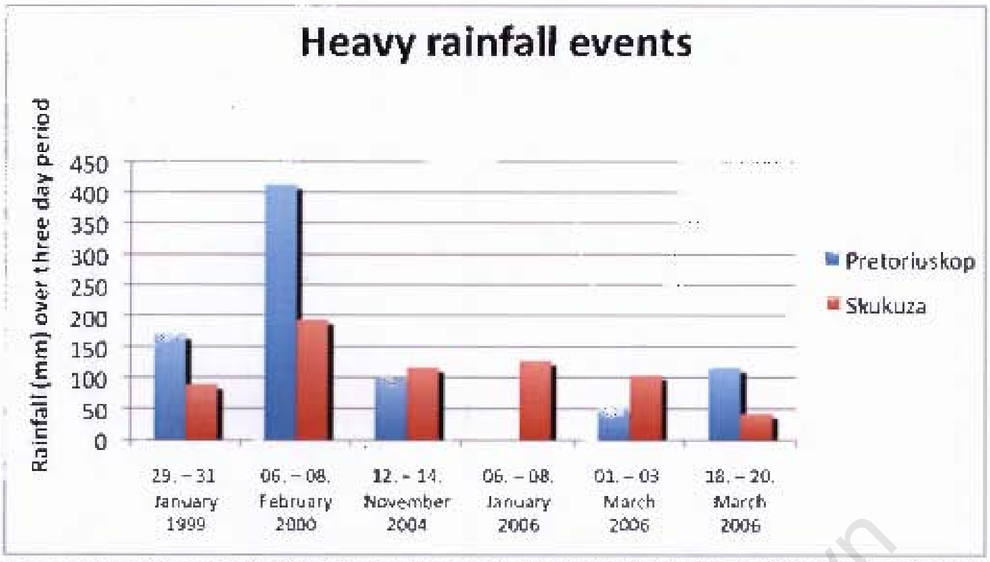


**Figure 5.4: Heavy rainfall events Pretoriuskop and Skukuza (1998 – April 2006)**

The heaviest rainfall took place in 2000, when it rained 413 mm in Pretoriuskop and 195 mm in Skukuza. This thus corresponds well with the fact that the 2000 heavy rainfall was the event most commonly mentioned by the farmers. Two farmers also mentioned heavy rainfall in 2006, while no farmers mentioned any heavy rainfall in 1999 or 2004. On the other hand farmers mentioned heavy rainfall in 1998 and 2005, events that were not found in the historical data, based on the 100 mm/3 days threshold.

**Rainfall changes over time**

For rainfall changes over time some statistically significant trends were detected, using the Mann-Kendall test and the uptrend test. The statistically significant trends were only detected at New Forest, where rainfall was found to be decreasing in January, February, April, May, July and November. This implies that rainfall is decreasing at the late start of the Rainy season, November, the middle of the rainy season, January and February, when the majority of rain falls, and at the very end of the rainy season, April and May. The graphs in figure 5.5 below illustrate the decrease that is detected for November, January and February.

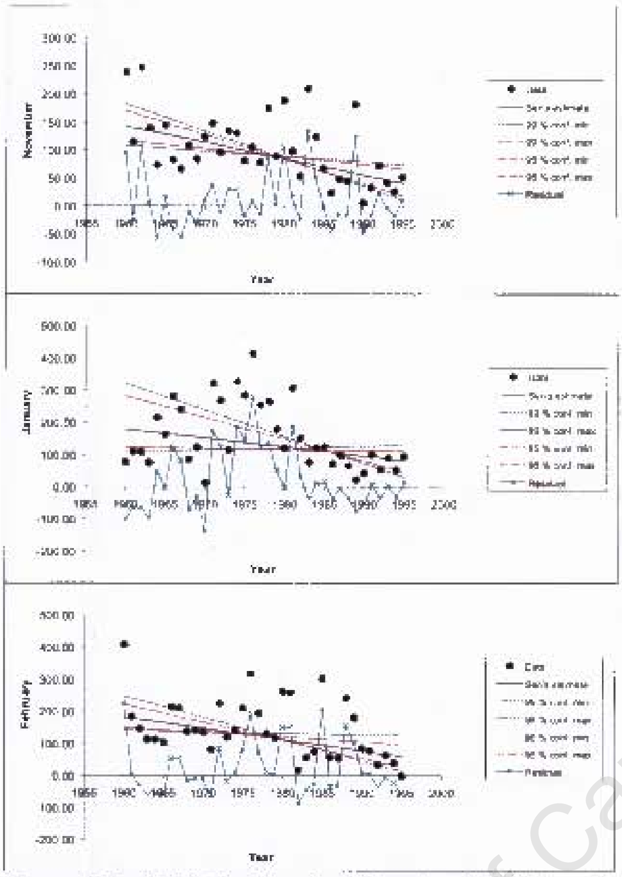

**Figure 5.5: Statistically significant rainfall trends for New Forest (mm)**

**Rainfall variability**

The rainfall variability is investigated looking at the percentage standard deviation of the recorded rainfall for each month, for each station, over the period 1960 to 1995. The percentage standard deviation is used in order to make the rainfall variability at the three stations, which have slightly different magnitudes of rainfall, comparable. As can be seen in table 5.4 below the percentage standard deviations are relatively similar for the different stations for the different months, and all are high. The greatest standard deviation is in the dry season, and so is related to minimal rainfall quantities. More importantly so though, is the fact that August and September, months in which the summer rainfall sometimes start, also show high variability. This could be related to the fact that the timing of the onset was found to vary quite a lot from year to year. October through April are not as variable, though all the months and all three stations are at all times showing a percentage standard deviation over 40%. So overall, the monthly rainfall seems to vary a lot from one year to the next. The variability in the annual rainfall is also relatively large, with the three stations varying between 26 and 35%. Considering for example Skukuza, which experiences on average 550 mm of rainfall every year, 26% is close to 150 mm, a large portion of the annual rainfall. These findings show that farmers in Bushbuckridge experience large variability in the mean monthly and annual rainfall.

| Percentage Standard Deviation | | | |
|---|---|---|---|
| | **New Forest** | **Pretoriuskop** | **Skukuza** |
| **January** | 66 | 59 | 73 |
| **February** | 63 | 66 | 88 |
| **March** | 64 | 78 | 71 |
| **April** | 84 | 90 | 81 |
| **May** | 93 | 115 | 124 |
| **June** | 168 | 198 | 207 |
| **July** | 211 | 224 | 267 |
| **August** | 93 | 99 | 103 |
| **September** | 149 | 147 | 170 |
| **October** | 60 | 62 | 76 |
| **November** | 58 | 43 | 59 |
| **December** | 58 | 53 | 52 |
| **Annually** | 35 | 28 | 26 |

**Table 5.4: Percentage standard deviation of mean monthly rainfall for the three stations over the period 1960 – 1995**



### How the perceptions and historical records correspond

Farmers' perception of rainfall variability seems to correspond well with historical records, as does the perceived decrease in rainfall. With regard to extreme events investigation was somewhat difficult, due to lack of data from recent years, and only two of the events mentioned by the farmers could be identified in the data.

### 5.1.3 Temperatures

High temperatures is the third most common trigger for coping and adaptation responses. This section will elaborate on high temperature events, as well as some perceptions of general temperatures and records. Only one out of the nine coping and adaptation responses to high temperatures was made by a farmer from the western villages, reflecting how the large majority of farmers who seem to be taking action on high temperatures are farmers from the eastern villages.

**Perceptions of temperatures**

Five high temperature events were mentioned as extreme events, but with only three of the farmers remembering the specific years, namely 1998, 2004 and 2010.

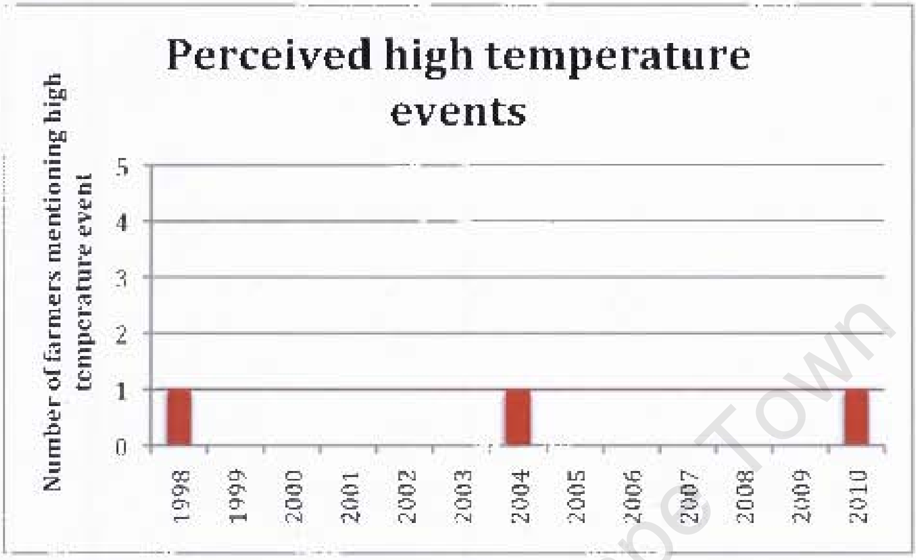


**Figure 5.6: Years of perceived high temperature events** (red highlights).

Though the farmers interviewed do not have any means of measuring temperatures, they feel that the temperatures vary from one year to the next, and that it has become warmer since when they started farming:

- Temperatures vary from one year to the next (21 interviewees).
- It has become warmer (13 interviewees).

Here it should be noted that six out of the 21 farmers who argue that temperatures vary from one year to the next make the argument based on the fact that they find the year of the interview, 2010, is very hot. There are also some contradictions between what the farmers say, like for example one farmer argues that last year was not very hot while another argues that last year was warmer than this year, and then another states that the last two years have not been very hot. It therefore seems that the perceptions of what high temperatures are and which have been the warm years is very subjective.

### Historical records

Due to a lack of temperature data for the last decade it is here only possible to investigate the extreme events prior to year 2000, so in this case only the year 1998. In order to see whether 1998 was really an unusually hot year, 1998 monthly average temperatures are here compared with the average temperature for the 1990s.

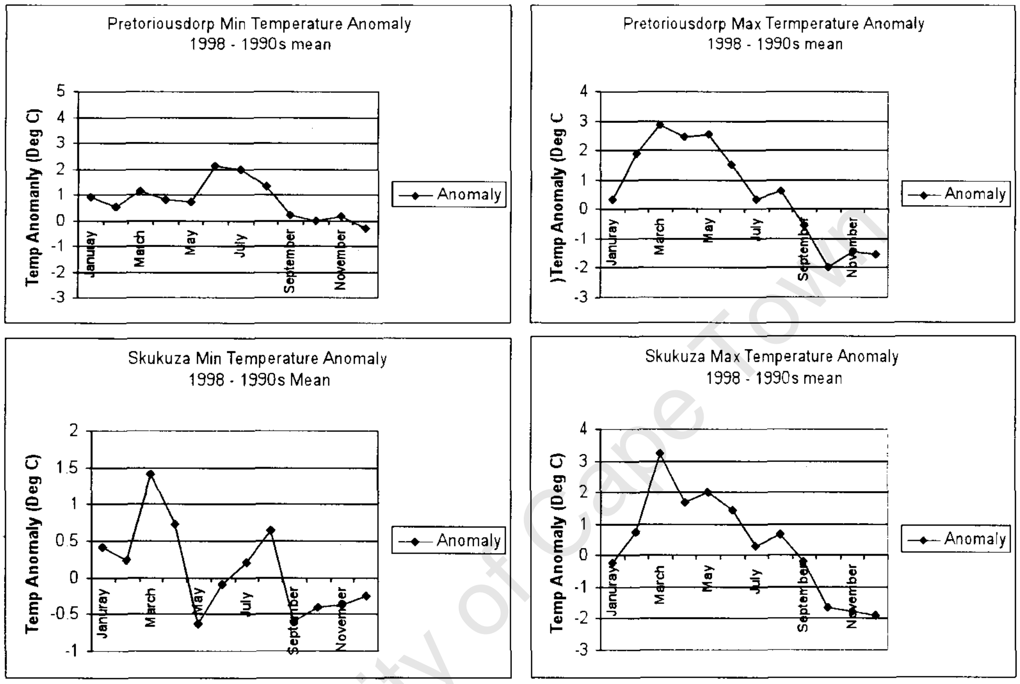


**Figure 5.7: Minimum (left) and maximum(right) temperature anomalies.** The graphs compare the mean monthly temperatures at Pretoriuskop and Skukuza in 1998 with the mean monthly temperatures for that decade.

When analysing the temperatures both maximum and minimum temperatures have been included, as an increase in either could be perceived as causing warmer than usual weather. As can be observed in the graphs in figure 5.7 above both the observed mean monthly maximums and the mean monthly minimums for 1998 are generally higher than the monthly means for the 1990s during the first eight months of the year. Interestingly so, the maximum and minimum temperatures for both stations agree that the temperatures are the same or lower than the decadal average for the last part of the year, September to the end of December. It is interesting that none of the farmers have mentioned these lower than usual temperatures, as they take place at a very important time of the year, the time when farmers plough and plant. While it could be related to them just not remembering, it could also reflect that the farmers do not find low temperatures as problematic as high temperatures.

With regard to change over time some farmers stated how it has become warmer over the years since they started farming. Looking at historical data statistically significant warming trends were detected, using the Mann-Kendall test and the nptrend test. This was mostly so for minimum temperatures, for which statistically significant warming trends were detected at Pretoriuskop for all months of the year except August and July, while at Skukuza for February, May and July. For maximum temperatures, there are only a few warming trends, in June at Skukuza.

### Temperature variability

Many farmers also claimed that the temperature generally varies from year to year. When looking at the historical data for the two stations, Skukuza and Pretoriuskop, there seems to be little variance though. Considering the period from 1960 to 1999, the standard deviation for mean monthly and annual maximum temperatures outlined in table 5.5 below is low, ranging from around 0,61 (annually), to a max of 1,85 (Skukuza, February). For minimum temperatures, the standard deviation ranges from 0,61 (annually), to a max of 1,69 (Skukuza, June). So it seems that the monthly average maximum and minimum temperatures vary very little from one year to the next.

| Standard Deviation | | | | |
|---|---|---|---|---|
| | **Maximum temperature** | | **Minimum temperature** | |
| | **Pretoriuskop** | **Skukuza** | **Pretoriuskop** | **Skukuza** |
| **January** | 1,44 | 1,43 | 0,77 | 0,72 |
| **February** | 1,74 | 1,85 | 0,85 | 0,76 |
| **March** | 1,37 | 1,50 | 1,14 | 1,13 |
| **April** | 1,28 | 1,35 | 1,03 | 1,15 |
| **May** | 1,27 | 1,27 | 0,93 | 1,14 |
| **June** | 1,23 | 1,13 | 1,17 | 1,69 |
| **July** | 0,94 | 0,89 | 1,23 | 1,43 |
| **August** | 1,15 | 1,14 | 0,86 | 1,08 |
| **September** | 1,32 | 1,28 | 0,98 | 1,24 |
| **October** | 1,47 | 1,41 | 1,15 | 1,37 |
| **November** | 1,23 | 1,29 | 1,06 | 0,93 |
| **December** | 1,73 | 1,59 | 1,01 | 0,79 |
| **Average** | **0,64** | **0,61** | **0,71** | **0,61** |

**Table 5.5: Standard deviation of the maximum and minimum temperatures at Pretoriuskop and Skukuza for the period 1960 to 1999**

**How the perceptions and historical records correspond**

Due to the lack of data it was somewhat difficult to compare the perception of extreme temperature events with historical records. Only one year, 1998, could be investigated, for which there was found to be unusually high temperatures, compared to the rest of that decade. With regards to changes in temperature, the warming perceived by farmers was to some degree reflected in the historical data. This was particularly so for minimum temperatures, were statistically significant warming could be observed more or less through the entire year. For maximum temperatures, only April and June showed warming trends. On the other hand, the temperature variability that was mentioned by some of the farmers could not be detected when considering mean monthly temperatures in historical data. This could be related to either miss-perceptions among farmers, or to the way the data was analysed. The analysis only considered monthly temperature means, which do not capture day-to-day variations.

## 5. 2 The vulnerability of small-scale farmers in Bushbuckridge

*Conducting a vulnerability analysis which looks at differential vulnerability to climate variability and extreme weather events, while also taking socio-economic and political issues into account*

The purpose of this section is to assess the vulnerability of small-scale farmers in Bushbuckridge. While the main focus is around the farmers' vulnerability to climate variability and extreme weather events, the research also incorporates analysis of social, political and economic factors. What is more, the assessment outlines how vulnerability differs between the farmers from the eastern and the western villages. It brings together structured and narrative analysis of qualitative data, in order to give a quantifiable and at the same time broad and contextualised perspective. To start off, analysis of the issues that farmers identify as their main problems in everyday life creates an understanding of the multi-stressor environment in which farmers live and work and of the underlying factors that can shape vulnerabilities. The analysis then goes on to analyse farmers' vulnerability to climate variability and extreme events, further highlighting some of the underlying factors that shape vulnerability.

### 5.2.1 Vulnerability to non-climatic factors

Farmers in Bushbuckridge were asked to outline what they think are the biggest problems that they face as farmers.[23] This question worked to highlight some of the underlying, non-climatic stressors that shape the vulnerability of farmers in Bushbuckridge. The main problems, which include water scarcity, animals eating and destroying crops, market issues and tractors, and the factors that were found to shape these problems, are outlined below.

#### Water scarcity

The most common problem mentioned was that of water scarcity. Surprisingly so, it was most commonly the farmers from the eastern villages, the farmers with irrigation systems, that mentioned water as a problem. Their water problems were often related to problems with the irrigation system. These water issues

[23] The farmers were allowed to mention more than one problem each.

can be linked to climatic factors, such as rainfall and temperatures, but here they can also be linked to political and socio-economic factors.

The irrigation schemes were originally developed and run by the Department of Agriculture and the Gazankulu Development Corporation, and all inputs and strategies were being provided for the farmers. Then, in more recent times, the farmers themselves became responsible, as the government post 1994 decided to pull out. While this was a great opportunity for the farmers in the irrigation schemes, who could now farm independently, it was also a challenge. Suddenly they had to provide input supplies, market opportunities, transportation and so on, elements that they were not used to dealing with. According to a senior extension officer this has been a big problem, especially as a lot of the farmers are old and so entrenched in the way things used to be.

*"You have to think for yourself, you have to do things on your own. So that's why you find that most of them are not responsible, because they think ah, previously somebody would come and do this for us, somebody will come and do that for us. And now this is no more. It is the attitude, the mindset. It is difficult to take people from the old set-up to the new set-up. That's the problem."*

(Senior extension officer)

*"It used to be the government [who cleaned out the silted dams], but not anymore, not since 1994."*

(Farmer from eastern village)

*"The farmers themselves can not do anything. Because when they check the costs, they are huge. To repair, to upgrade, all the infrastructure it is very, very costly."*

(Senior extension officer)

*"But then, it is not a problem per se of water scarcity, there's the problems the way of sharing it. There is that tendency of like, you know, with people everyone needs something for himself, you see."*

(Junior extension officer)

With the new set-up in the schemes came other challenges too. Group dynamics, and managing the irrigation schemes collectively is also challenging. As was argued by a young extension officer, there is not necessarily a water scarcity problem, but more a problem of sharing.

The farmers also face many problems with the actual irrigation system, including silted dams, dysfunctional valves and clogged canals, but they lack the financial means to deal with them. In order to try and deal with the problems the farmers have organised themselves within the irrigation schemes, and they have approach Department of Water Affairs and Department of Agriculture for help. According to an ex-farmer who now works in MABEDI, a development initiative trying to assist farmers in the irrigation schemes, Government Departments have tried to help, but there has been lack of consistency, planning and resources.

So for the farmers from the eastern villages, in the irrigation schemes, the water problems go far beyond the stress caused by climatic factors. As has been outlined above, the complicated political and socio-economic context also plays a crucial role in the farmers' access to water. For the farmers from the western villages, where they have never had the irrigation systems nor the government support, the water problems seem to depend more on climatic factors. There, water scarcity was most commonly related to rainfall dependency, to high temperatures and to lack of rainfall.

So looking at the underlying stressors, that are causing water problems has shown that first of all, water issues are not only related to climatic factors, but also to socio-economic and political factors and processes. Secondly, it has shown that the stressors and the water scarcity context is very much community specific, as reflected in the difference between the eastern and western villages, communities which are no more than a 40 minutes drive from each other.

**Animals eating and destroying crops**

The second most common problem mentioned by the farmers is animals walking into the fields, destroying and eating the crops. This problem seems to be far more common in the western villages than in the eastern villages, and while it is most commonly cows, moles, monkeys and hippos are also mentioned. One of the farmers in Phelandaba, one of the western villages, says that the Induna[24] tells cattle owners to look after their cattle when the majority of people plough and plant. It seems that this is not always carried through though, and what is more, the farmers don't always plant and plough at the same time. The problem seems to be biggest in the wetland fields, as a lot of the farmers have proper fences in their homesteads. While they do build some fences in the wetland, using wood and branches that they collect in the area, these are not always strong enough, and so the cattle break through.

The farmers from the western villages say that they do not have proper fences in the wetland because they cannot afford it. So while the problem is animals eating and destroying crops, which is linked to the lack of fencing, the underlying issue is actually the lack of financial means.

**Picture 5.1: Fencing in the wetland.** Animals quite easily break through these home-made fences

[24] The Induna is appointed by the local chief, and functions as a local spokesperson and mediator.

A discussion with one of the farmers from the western villages, who farms both in the wetland and her homestead garden, about the dry summer of 2008/2009 also brought out an interesting perspective. While the wetland has more moisture, and so generally better conditions for growth than the homestead during dry periods, it turned out that cows had destroyed the crops in the wetland. Therefore, during that dry summer, the homestead had produced the better yield. This is a good example of how the animal and fencing factor actually overrides the impact of the climatic stressor, in this case drought.

In the eastern villages, only three farmers mentioned problems with animals eating and destroying crops, and in their case it did not seem like the problem is a lack of fencing. There many of the farmers have fencing, and the problems with animals eating and destroying crops was said to come from people leaving the gates open or breaking the fences so that the cattle could get in.

So looking at the problems with animals eating and destroying crops has highlighted further differences between the eastern and the western villages. What is more, it has shown that the problem is linked to an underlying issue of financial capacity.

**Market issues**

Market problems were found to be common among the farmers from the eastern villages. There seems to be several market issues, one related to there being too many farmers growing the same crops and selling at the same time. This pushes the prices down, and can even make it impossible to sell the crops as the market becomes saturated. This seems to be the case for tomatoes, a crop grown by 19 out of the 23 farmers interviewed in the eastern villages. One of the farmers said that market saturation did not use to be a problem, as there was a tomato jam factory in Hoedspruit to which it was always possible to sell tomatoes. This reflects how vulnerable the farmers are to changes in the market, like the move or closure of a factory, and how it seems to be difficult for the farmers to chose the crops they grow according to the market demand.

Another market issue is that of finding a place to sell the crops. Like one farmer said, his crops are not good enough for the national market. What is more, the farmers do not have experience in marketing.

*"The market it's a big problem. And, you see, previously the government was organising the market for the farmers. And now the farmers have to organise the market for themselves."*

(Senior extension officer)

Transporting crops to the market is another market related issue. Just under half of the farmers from the eastern villages sell their crops to people who come to their field or house to buy, and/or they sell it along the road or at the local market. While they don't have to spend money on transportation, they often have to sell their products at a low price. Well over half of the 23 farmers interviewed from the eastern villages also transport their crops to markets and shops in neighbouring villages. Only two of these farmers have free access to a bakkie for transportation. The others generally rent bakkies, paying on average between R200 and R300 (depending on the location and load). Several of the farmers mentioned that MABEDI, the development initiative, helps them with transportation. MABEDI would currently pay half the cost of transportation, with the long-term view of withdrawing, as the farmers become more established, and leaving them with full responsibility. Generally though, the farmers from the eastern villages said that it is difficult for them to afford transportation for the crops.



Among the farmers from the western villages, market issues were not mentioned as one of their problems. There, six of the 19 farmers interviewed farm purely for their own and their family's consumption, while the rest sell to people who come to their field or their homestead or at the local village market. Only two of the farmers also occasionally transport crops to Acornhoek, a town in the area.

So, as was outlined above, only a tiny portion of the farmers from the western villages sell their crops beyond local markets, while the majority of the farmers from the eastern villages do. What is more, farmers from the eastern villages face several market related issues, including market saturation, access to markets, affordability of transport and vulnerability to changes in the local markets.

### Tractors

Tractors for ploughing is another problem highlighted by farmers from the eastern villages. A project by the Department of Agriculture, Masibuyele Emasimini, is currently providing tractors for farmers from the eastern villages,[25] free of charge. While it is a great initiative from the Department, the farmers complain that there are not enough tractors, that they queue and queue, waiting for their turn to plough. Because there are so many farmers, there are often not enough tractors for everyone to plough in time for when seasons start. This has especially become a problem after Masibuyele Emasimini was expanded last year, to also provide tractors for farmers who are not in irrigation schemes. So while this project is extraordinary, in that it provides a free service for the farmers, it seems to have also made farmers dependent on its tractors. This makes farmers vulnerable to problems within the Masibuyele Emasimini project, like shortage of tractors, or to political decisions within the Department of Agriculture that change or put an end the project.

While the current tractor problems are related to a shortage of tractors in Masibuyele Emasimini, the issue is further related to an underlying factor, namely financial capacity. As one farmer said, if she had enough money she could deal with the tractor problem by renting one.

### Differential vulnerability to multiple non-climatic factors

Analysis of the different problems farmers face in everyday life has illustrated how farmers live and work in a multi-stressor environment. They are impacted by political, economic and social factors that can sometimes override the stress caused by climatic factors. The analysis has also shown some of the differences between the western and the eastern villages, illustrating the location specific nature of vulnerability. The section thus highlights the importance of location specific vulnerability studies, as well as the importance of taking a multi-stressor approach. What is more, the analysis has also shown how a lot of the issues are

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[25] The project does not comprise the western villages, and this is probably related to the fact that the project was initially linked to the irrigation schemes.

linked to financial capacity, and that with the right financial means farmers could deal with many of their issues, from the irrigation system to problems with animals eating and destroying crops.

### 5.2.2 Differential vulnerability to climate variability and extreme weather events

When here assessing the vulnerability of small-scale farmers in Bushbuckridge, the focus is on their vulnerability to climate variability and extreme weather events. This analysis is done by looking at the proportion of farmers being in a favourable condition with regard to each vulnerability indicator, while at the same time drawing on more soft data from the interviews and focus group discussions with the farmers.

#### 5.2.2.1 Exposure

Exposure, is here concerned with the extent to which farmers in Bushbuckridge are experiencing climate variability and extreme weather events. This includes an analysis of variability in the timing of the onset, of mean monthly and annual rainfall variability, of mean monthly temperature variability and of the number of droughts and heavy rainfall events.

**Variability in the timing of the onset**

Variability in timing of the onset was investigated in section 5.1.1, where it was found that the farmers in Bushbuckridge experience a large variability in the timing of the onset of the summer rainfall.

**Variability in the mean monthly and annual rainfall**

Variability in the mean monthly and annual rainfall was investigated in section 5.1.2, where it was found that the farmers in Bushbuckridge experience a large variability in the mean monthly and annual rainfall.

**Variability in mean monthly temperatures**

Variability in the monthly temperatures was investigated in section 5.1.3, where it was found that the farmers in Bushbuckridge experience very little variability in mean monthly maximum and minimum temperatures.[26]

**Extreme weather events**[27]

When considering the farmers' exposure to extreme weather events the focus is on two types of events, namely heavy rainfall events and droughts. Heavy rainfall events are defined as events with over 100 mm of rainfall over a period of three days. Droughts are defined as three-month periods during the rainy season where rainfall falls within the 20th percentile, so are exceptionally low, while at the same time average temperatures fall outside the 80th percentile, so are exceptionally high. Table 5.6 and 5.7 below outline the number of droughts and heavy rainfall events detected in historical data over the period 1960 to 1995.



| *Number of rainfall events with over 100 mm of rainfall over a period of 3 days* | | | | |
|---|---|---|---|---|
| | *Between 100-150 mm* | *Between 150-200 mm* | *Over 200 mm* | *Total events* |
| ***New Forest*** | 19 | 2 | 2 | *23* |
| ***Pretoriuskop*** | 12 | 4 | 0 | *16* |
| ***Skukuza*** | 12 | 2 | 1 | *15* |
| ***Average*** | | | | *18* |

**Table 5.6: Number of heavy rainfall events at each station for the period 1960 – 1995**

[26] While daily temperatures are not a focus in this study, it is important to note that the lack of variability in mean monthly temperatures does not exclude the possibility that farmers are exposed to variability in the daily temperatures.

[27] Note that this analysis is kept seperate from the heavy rainfall analysis is section 5.1 because section 5.1 focuses on capturing recent rainfall events perceived by farmers. The focus here is to get an understanding of heavy rainfall events over time, and so looks at the longest period of time for which there are records from all three stations, 1960-1995, and therefore includes data from New Forest.

Considering the average number of events across all three stations, 18 events over a period of 36 years, it can be found that the farmers are exposed to frequent heavy rainfall events. This is mostly to the smaller heavy rainfall events of between 100 and 150 mm over a period of 3 days.

| *Number of droughts* | |
|---|---|
| ***Pretoriuskop*** | ***8*** |
| ***Skukuza*** | ***8*** |

**Table 5.7: Number of drought events at each station for the period 1960 – 1995**[28]

As can be observed in table 5.7 above, eight droughts were detected in Pretoriuskop and Skukuza. This can be considered a relatively small number of events over a period of 36 years. It can therefore be said, using this method for detecting drought, that droughts are relatively infrequent in Bushbuckridge.

It is important to note that there should not be too much emphasis on the specific number of drought and heavy rainfall events detected, given a somewhat simple and limited methodological approach. Still, one can note that, using this methodology, farmers seem to be only half as exposed to droughts as they are to heavy rainfall. These findings correspond with findings in the interviews, where more farmers told of crop losses due to heavy rainfall than crop losses due to droughts. Importantly so, based on the methodological approach taken in this research, it can be found that the farmers are more vulnerable to heavy rainfall events than they are to droughts.

**Exposure to climate variability and extreme weather events**

Analysing climate variability, it was found that farmers are more exposed to more variability in the timing of the onset of the summer rainfall and to variability in the mean monthly and annual rainfall, than they are to variability in mean monthly temperatures. With a standard deviation of between 40 and 50 days, farmers in Bushbuckridge are exposed to a large variability in the timing of the onset of the summer rainfall. They are also exposed to a large variability in

[28] This data is only available from two stations, Pretoriuskop and Skukuza, due to the lack of temperature data from New Forest.

the mean monthly and annual rainfall. For mean monthly maximum and minimum temperatures, on the other hand, farmers in Bushbuckridge are not exposed to any significant variability.

The analysis of extreme weather events found that the farmers in Bushbuckridge are exposed to relatively frequent heavy rainfall events, with an average of 18 heavy rainfall events detected over a 36-year period. On the other hand, they are exposed to a smaller number of droughts, with an average of eight droughts detected over a 36-year period. So, based on the methodology used here, it was found that while the farmers in Bushbuckridge experience a heavy rainfall event every second year, they only experience droughts every four-five years. This indicates that farmers are only half as exposed to droughts as they are to heavy rainfall.

#### 5.2.2.2 Sensitivity and resilience

The table below outlines the sensitivity and resilience of farmers from the eastern and the western villages according to the indicators that were chosen.

| Category | Indicator | Description | % of the 23 farmers from the eastern villages (actual number) | % of the 19 farmers from western villages (actual number) | Most vulnerable |
|---|---|---|---|---|---|
| *Sensitivity* | Irrigation | Proportion of farmers that have irrigation | 100.00% (23) | 5.26% (1) | Western villages |
| | Education (out of 30)[29] | Proportion of households that have one or more members who have completed primary education, Grade 7 | 100.00% (16) | 92.86% (13) | Western villages |
| | Crop damage from extreme events | Proportion of farmers who mentioned one or more events where they had lost some, a lot or all of their crops | 69.57% (16) | 94.74% (18) | Western villages |
| *Resilience* | Off-farm employment | Proportion of households that have one or more family member with off-farm employment | 30.43% (7) | 68.42% (13) | Eastern villages |
| | Government support | Proportion of the households receive monthly government grants | 56.52% (13) | 89.47% (17) | Eastern villages |
| | Support from friends/family | Proportion of farmers receiving some form of support from family or friends not currently living in the household | 21.74% (5) | 5.26% (1) | Western villages |
| | Access to insurance | Proportion of the farmers who have insurance | 0.00% (0) | 0.00% (0) | Equally western and eastern villages |
| | Access to credit | Proportion of the farmers who have borrowed money | 17.39% (4) | 10.53% (2) | Western villages |
| | Membership in farmers' organisations | Proportion of the farmers that are members of farmer organisations | 86.96% (20) | 0.00% (0) | Western villages |
| | Crop diversification | Proportion of the farmers growing 4 or more different crops | 82.61% (19) | 73.68% (14) | Western villages |

**Table 5.8: The sensitivity and resilience of farmers from the eastern villages compared to that of the farmers from the western villages**

As can be seen above the farmers from the western villages are more sensitive than farmers from the eastern villages when considering all three sensitivity indicators. The farmers from the western villages are also less resilient than the farmers from the eastern villages, in four out of seven resilience indicators.

[29] In the case of education only 16 of the farmers from the eastern villages and 14 of the farmers from the western villages provided answers that could be used for analysis.

If having a closer look at the indicators though, it can be found that the eastern villages do not score much higher than the western villages on three of the resilience indicators, namely support from family and friends outside the household, access to credit and crop diversification. So for these resilience indicators, the difference between the eastern and the western villages are not that big. With regard to membership in farmer organisations, on the other hand, the difference between the two is much more significant, 87% in the eastern villages versus 0% in the western villages.

For the indicators where the western villages had the best scores, off-farm employment and Government support, the differences are also relatively large, reflecting how the farmers from the western villages have significantly more family members with off-farm employment and receive significantly more government support, than the farmers from the eastern villages. For the last resilience indicator, the eastern and the western villages have equal scores, with none of the farmers having access to insurance.

With regard to the sensitivity indicators, the eastern villages score significantly better with regard to irrigation, and have lost significantly less crops to extreme events than the western villages. For education, on the other hand, the difference between the eastern and the western villages is minimal. So while overall the farmers from the eastern villages can be seen as less vulnerable than the farmers from the western villages, the difference is not as clear as it may initially seem.

#### 5.2.2.3 Bringing it together – exposure, sensitivity and resilience

The vulnerability analysis has looked at the three components, namely the exposure, sensitivity and resilience of the farmers in Bushbuckridge.

Based on the indicators that were used here, the farmers from the western villages were found to be more sensitive and less resilient than the farmers from the eastern villages. The farmers from the western villages are therefore more vulnerable than the farmers from the eastern villages to exposure to climate variability and extreme weather events. The climatic stressors to which they are most exposed include variability in the onset of the summer rainfall, variability in mean monthly and annual rainfall, and heavy rainfall events.

The vulnerability analysis has thus highlighted the location specific nature of sensitivity and resilience, while at the same time uncovering some of the similarities across the eastern and the western villages.

## 5.3 Coping with and adapting to climatic stressors

*Analysing the different mechanisms by which farmers are coping with and adapting to climatic stressors, and consider potential adaptation thresholds*

The aim of this section is to outline the mechanisms by which the farmers were found to cope with and adapt to the main climatic stressors, namely; late onset; heavy rainfall; and high temperatures. The different mechanisms by which the farmers are dealing with these stressors are divided into coping and adaptation mechanisms. While coping is here defined as the short-term capacity or ability to survive, adapting is defined as more sustainable, long-term adjustments. This does not necessarily imply that it is always clear what is an adaptation and what is a coping mechanism, as the distinction between the two can depend on the context. To take an example, mulching can be seen as a coping mechanism if the farmer decides to do mulching one summer when he is experiencing high temperatures and lack of moisture in the soil. On the other hand, if the farmer makes mulching a permanent part of his farming mechanisms, as a response to a general increase in temperatures, it can be seen as an adaptation mechanism. The different coping and adaptation mechanisms used by the farmers in Bushbuckridge are outlined in table 5.9 below. They are divided into coping (green) and adaptation (red), based on the context in which they are used.

| Coping/adaptation mechanisms | Late onset | Heavy rainfall | High temperatures |
|---|---|---|---|
| Delay ploughing/planting/farming | X | | |
| Delay ploughing/planting/farming in homestead but not in wetland | X | | |
| Fetch water in river | X | | |
| Plant smaller area | X | | |
| Plant more if the rain comes | X | | |
| Plant cassava and maize | X | | |
| Avoid planting specific crops | X | | |
| Add soil after erosion | | X | |
| Irrigate/ irrigate in the morning and evening/avoid irrigating in the day when the water is hot/Irrigate more often | | | X |
| Delay or shifting the planting season | | | X |
| Weed in the morning | | | X |
| Irrigate | X | | |
| Not cut down natural vegetation/ growing vetiver grass | | X | |
| Build furrow | | X | |
| Grow vegetation in the furrows | | X | |
| Make bendy, not straight, furrows | | X | |
| Plough shallow | | X | |
| Locate the field away from the water way | | X | |
| Raise the beds | | X | |
| Do mulching | | X | X |
| Build a tank | | X | |
| Plant early, making the crops strong before the heavy rain | | X | |
| Use sprays | | | X |
| Leave grass between the tomato plants | | | X |
| Nothing to do – can not afford buying nets/build greenhouse | | | X |

**Table 5.9: Outline of the different coping mechanisms (green) and adaptation mechanisms (red) as a response to the three stressors, late onset, heavy rainfall and high temperatures (horizontal)**

In order to get an understanding of the different mechanisms it is also important to look at the different impacts related to the three stressors. The impacts are outlined in table 5.10 below, and will be discussed further in relation to each of the stressors.

| IMPACTS | | |
|---|---|---|
| **Late onset** | **Heavy rainfall** | **High temperatures** |
| Irrigation water not enough | Crops become degraded or are eroded | Shortage of water |
| Water scarcity as rivers/dams run dry → friction among the farmers | Crops die | Soil quickly dries after irrigating |
| Increasing uncertainty over planting/preparation dates | Maize grows tall, but does not bear fruit | Crops burn in the sun (especially tomato) |
| Too dry to plough/plant – sometimes have to delay | Farmers can't go to the field, and so crops and weed grow uncontrolled | Plants become weak or die |
| The crops don't grow well or seeds die | | More insects that eat or destroy crops |
| | | More crop disease |

**Table 5.10: Impacts experienced from the different stressors**

When investigating impacts it can also be important to look at the type of extreme events that cause the most impact. Table 5.11 below outlines events mentioned by farmers and associated losses. As can be seen in the table, heavy rain and flooding is overall the most common extreme event mentioned, though only twice causing a loss of all crops. The second most common extreme event mentioned is drought. For droughts, on the other hand, six events are mentioned where all crops were lost. Farmers' recollection of events and losses therefore indicates that while heavy rainfall and flooding is by far the most common extreme event in the area, drought tends to cause more severe damage to crop yields. So while the farmers are more frequently experiencing losses due to heavy rain and flooding, droughts, though less frequent, seem to cause a greater impact.

| Extreme events (stressor) | Events where some/a lot of the crops died | Events where all the crops died | Total |
|---|---|---|---|
| Drought | 10 | 6 | **16** |
| Dryspell | 1 | 1 | 2 |
| High temperatures | 2 | 1 | 3 |
| Very cold at night | 1 | 1 | 2 |
| Hail | 1 | 1 | 2 |
| Heavy rain/flooding | 19 | 2 | **21** |
| Strong wind | 1 | 0 | **1** |
| **Total** | **35** | **12** | **47** |

**Table 5.11: Loss of crops due to extreme weather events.** Based on all 42 farmers interviewed, with some farmers mentioning several events and others not mentioning any events.



The last focus of this chapter is on adaptation thresholds. Applying the definition outlined by Adger et al. (2009b), the threshold beyond which adaptive actions no longer reduce vulnerability, this research looks at limits to agricultural adaptation, the point beyond which farming objectives, under current practices and adaptation mechanisms, can no longer be maintained.

### 5.3.1 Late onset of the summer rainfall

Late onset refers to the timing of the onset of the summer rainfall.

#### 5.3.1.1 Impacts of late onset

- Increasing uncertainty over planting/preparation dates
- Too dry to plough/plant – sometimes have to delay
- Plant – but then crops don't grow well or seeds die
- Irrigation water not enough
- Water scarcity as rivers/dams run dry ⟶ friction among the farmers

In relation to a delay in the onset of summer rainfall farmers voiced difficulties around farm management decisions, such as Increasing uncertainty over planting and preparation dates. While some farmers said that they would wait for the rain before ploughing and planting, other farmers said they would still plant but that if the rain kept delaying then they would not get good crops or the crops simply would not grow. As one farmer said, the maize takes time to germinate when the rain comes late. In some cases farmers said the soil would be too dry to even start ploughing or planting, and while it is somewhat easier for those with irrigation, some argued that irrigation water is simply not enough for the crops. What is more, late rainfall can lead to a general lack of water as the dams and rivers run dry. This creates friction between the farmers in the irrigation schemes, and there were claims that some farmers would sleep in their fields in order to misuse the irrigation system and steal water. The irrigation schemes have schedules for who can water when, but as one lady pointed out, she is sometimes unable to irrigate as the water would run out before it is her turn.

#### 5.3.1.2 Coping Mechanisms

The coping mechanisms discovered in relation to a delay in the onset of the summer rainfall are all outlined in the table 5.12 below. All but one are short term adjustments, and thus coping mechanisms rather than adaptations. While responses to late onset are made by farmers from both the eastern and the western villages, they are a lot more common amongst farmers from the western villages. This could be related to the fact that the farmers from the western villages do not have irrigation, and so depend on rainfall for their farming activities.

| Coping/adaptation mechanism | Interviews | | Focus group discussions[30] | |
|---|---|---|---|---|
| | Eastern villages (n=23) | Western villages (n=19) | Eastern villages (n=16) | Western villages (n=7) |
| Delay ploughing/planting | 6 | 5 | 2 | 0 |
| Delay ploughing/planting in homestead but not in wetland | 0 | 8 | 0 | 3 |
| Fetch water in river | 0 | 2 | 0 | 1 |
| Plant smaller area | 1 | 0 | 12 | 0 |
| Plant more if the rain comes | 1 | 0 | 0 | 0 |
| Plant cassava and maize | 0 | 0 | 1 | 0 |
| Avoid planting specific crops | 0 | 0 | 2 | 2 |
| Irrigate | 0 | 0 | 1 | 0 |

**Table 5.12: Number of farmers mentioning the different coping (green) and adaptation (red) mechanisms in response to late onset of summer rainfall.** The table distinguishes between the coping and adaptation mechanisms that were brought out in the interviews and those that were brought out in the focus group discussions.



To delay farming activities, such as ploughing and planting, is one of the most common ways to cope with delay in the onset of the summer rainfall, and this response is practiced almost equally by farmers from the eastern and western villages. Another common coping mechanism, delaying ploughing and planting in the homestead but not in the wetland, is only available to the farmers from the western villages, where most of the farmers have two fields, one in the wetland and one in the homestead.[31] The wetland provides some moisture, allowing farmers to farm even when the rain has not yet started. According to some farmers though, the wetland is not quite wet enough without rain, and one therefore has to carry water from the river to the field. This seems to depend on

[30] Note that only 26 farmers attended the focus group discussions. While all the focus group discussions in the western villages focused on late onset, only two out of the three in the eastern villages did (therefore 16 and 7).
[31] Note that some of them actually also have a third field up on the mountain.

the location of the field in the wetland, the closer to the river the moister the fields.

Planting a smaller area and planting more if the rain comes again are both responses mentioned by irrigation farmers. Farmers are here cautious, and plant a small area if there is some initial rain, but wait to plant more until they see that it is really the start of the summer rainfall. Planting a smaller area, will potentially help reduce the loss of crops if the rainfall keeps delaying. For the irrigation farmers, for whom the irrigation water has been found to run short when the rain starts late, planting a smaller area enables them to use the water to keep some crops healthy rather than just keeping a lot of crops from dying.

As came out when looking at the impacts of late onset of summer rainfall, a delay in the onset can lead to water scarcity as rivers and dams run dry. This, together with the fact that some farmers mentioned that irrigation water is not enough, could be the reason why irrigation as an adaptation mechanism has only been mentioned by one farmer. So while irrigation is looked upon as a common way to deal with rainfall variability (Gbetibouo, 2009), it was not commonly mentioned by farmers in Bushbuckridge as a way to deal with late onset of summer rainfall. This could also be related to what has been mentioned in earlier chapters, namely the fact that their irrigation systems are old and seemingly unreliable.

Then, several farmers, both from the western and eastern villages, mentioned that it is quite specific when one can and can not plant specific crops, like peanuts, and so when the rain is late they do not plant them. One irrigation farmer also mentioned that when it is dry and warm he will plant specific crops, like maize and cassava, presumably because these crops are most capable of dealing with the warm and dry conditions. The next section, which looks into thresholds in relation to delaying planting in order to deal with late onset, will look at the growing season and requirements for different crops in more detail.

#### 5.3.1.3 Thresholds

For onset related thresholds the focus was on one coping mechanism, namely delaying planting. Trying to establish some form of threshold, a point beyond which the farmers could not delay their farming activities[32] while waiting for the rain to start, proved easier said than done. This is partly because farmers would make contradicting statements and partly because it seemed to be difficult for them to say a specific time beyond which they are unable to plant. It was thus problematic to find any conclusions around a general threshold beyond which they can't plant. The focus therefore became to look at the best planting times for the different crops, and table 5.13 below gives a summary of the different statements (each cell represents one statement) that were made around planting times. In order to really focus attention on the best planting times of the most common crops the last three focus group discussions featured an exercise that focused specifically on outlining this.[33]



[32] Note that the this does not include delaying ploughing/planting/farming in the homestead but not in the wetland.

[33] This exercise is described in more detail in the methodology.

| Crop | Best Planting time | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Maize (701) | Aug | | Aug/ Sept/ Oct/ Nov | July/ Aug/ Sept | | | | |
| Maize (Kalahari) | Dec | | Dec/Jan/Feb | Nov/ Dec | | | | |
| Maize (general) | Nov/Dec, but if you plant in Jan you don't get enough | | Feb | Dec/ Jan | | | | |
| Tomato | Jan | | March | Any time | 1st week of December if the rain comes | | | |
| Pumpkin | Aug | | Oct/Nov | Feb | Dec/Jan | | 1st week of Dec if the rain comes | |
| Beetroot | Jan | | Oct | Any time | | | | |
| Madumbis | Sept, Oct, Nov, Dec at the latest | | Oct, if you plant in Dec they don't grow | | | | | |
| Cabbage | June | | May | Any time | | | | |
| Dry beans | March | | Jan/ Feb/ March, April not good | Feb | | | | |
| Peanuts | Oct | Nov/ Dec, not Jan | Sept/ Oct/ Nov (when rain comes), Dec not good | Late Oct/ early Nov | Nov, not Dec | Nov | Aug/ Sept | Oct |
| Butternut | March | | Sept | Aug/ Sept/ Oct/ Nov | | | | |
| Sweet potato | Dec/Jan or until March/when the rain stops | | Oct | Dec, Jan is not good | | | | |
| Bambara nuts | Mid Jan at the latest | | Jan | | | | | |
| Cassava | Oct | | Nov/ Dec, Jan not good | Any time | | | | |
| Cowpeas | Nov | | Dec | Nov/ Dec | Aug, Nov at the latest | | | |
| Chilli | Aug | | Nov/ Dec | No specific season | | | | |

**Table 5.13: Good planting times.** Statements made by different farmers in the different focus group discussions. The planting times that were decided on by the farmers together in the last three focus group discussions[34] is marked in bold, while the planting times that were stated by individuals across all the focus group discussions are in normal font. Blue font refers to where there is agreement around a planting time, so when a month/period has been mentioned twice or more. Red font refers to when there are completely contradicting statements. The statements made by farmers from the western villages have been coloured yellow, in order to distinguish between the eastern and the western villages.[35]



[34] These are the focus group discussions that featured an exercise specifically focused on outlining planting times.
[35] The differences between the farmers from the western and eastern villages have not been explored to any depths here though, and so the coping range of the two will not be distinguished.

The first of the three important points that stand out in table 5.13 is that for some crops a wide span of planting times have been mentioned. This is the case for maize (701), maize (Kalahari), maize (general), pumpkin, madumbis,[36] dry beans, peanuts, butternut, bambara nuts and cowpeas. The second point that stands out is that for some crops, namely tomato, beetroot, cabbage, and cassava, there is absolutely no agreement around the planting times. Lastly, it is important to note that for some crops there are clear contradictions about when it is good to plant, with some farmers or groups saying that one month is good for planting, and another farmer or group saying that that particular month is not good for planting. This is the case for planting madumbis, peanuts and cowpeas in December, and for planting sweet potato in January.

What is clear from the three points that have been made here is that, given that a wide span of planting months are sometimes stated, there is not necessarily a specific time at which the crops have to be planted. This can be related to the nature of the crops or to the fact that the planting time also depends on the timing of the onset. What is more, it could be that some of the crops can be grown at very different times of the year.

Establishing some form of threshold, a point beyond which farmers are no longer able to plough and plant and still produce sufficient yield, can be done by focusing on the contradicting statements around planting times. Starting with madumbis,[37] there was one focus group saying that one can plant in December at the latest and another group saying that one cannot plant in December as the madumbis will not grow. This could indicate that at some point in December it goes from still being favourable to plant madumbis to being unfavourable to plant madumbis. So if the rain has not started by this point in December, and the farmers have been unable to plant, then it can be deduced that they will not be able to get a sufficient madumbis yield.

For peanuts there were a lot of statements around planting times, and peanuts were often mentioned as a crop that cannot be grown if the rain came late. As with madumbis, it seems that the threshold could be in December. While one

[36] A root vegetable, commonly grown in the wetlands by the farmers without irrigation
[37] Madumbis is mainly grown in the wetland by the farmers without irrigation.

focus group discussion group states that peanuts can still be planted in December but not in January, others state that November is ok but December is not good for planting peanuts. The planting times for cowpeas also indicate some form of threshold in December, as two focus group discussion groups state that one can still plant in December while one farmer argues that one can plant cowpeas in November at the latest.

It here seems that for the three crops, madumbis, peanuts and cowpeas, there could be a threshold in December beyond which planting is unfavourable, thus leaving the farmers with insufficient yields. If the rain starts in late December, or as late as January, it can thus be deduced that a threshold is exceeded, and that farmers are unable to produce sufficient yield from certain crops.

Importantly though, exceeding the threshold does not imply a total collapse in the household. The ability of a household to deal with the delay in onset one year will depend on their sensitivity and resilience, so the degree to which other factors that can buffer their loss of income and food are in place. As was outlined when analysing vulnerability, many farmers have government grants or family members with off-farm employment. This might enable them to get by until the next planting season, though they may not be able to plant as much as they normally would.

Another point that is important to mention is the fact that it is not necessarily just a delay in summer rainfall that delays ploughing and planting. One farmer, for example, had lost her husband the year before, and had therefore been unable to plant before December that year. Another reason that some farmers were found to have to delay their planting is that they are waiting for tractors to plough. This is only the case in the irrigation schemes, where the farmers share a number of tractors through the Masibuyele Emasimini project.[38] The sharing means long queues and frequent delays, and makes farmers unable to plough and thus plant at the time they would choose. At the time of one of the focus group discussions, on the 29th of November 2010, around two weeks after the



[38] The Masibuyele Emasimini project is outlined in more detail in section 5.2.1, vulnerability to non-climatic factors.

summer rain had started, several farmers were still waiting for tractors to plough parts of their fields.

Analysis of planting times for different crops has here made it possible to establish that there is some form of threshold in December. For madumbis, peanuts and cowpeas it seems that planting cannot be delayed beyond some point in December, as the crops will then produce insufficient yields. Importantly so, as outlined above, a delay in the onset of the summer rainfall is not the only stressor that can delay planting times. It can therefore be found that the December threshold can be exceeded due to a number of factors.

### 5.3.2 Heavy rainfall

Heavy rainfall events have been defined as events where an area experiences 100 mm or more rainfall over a period of three days.

#### 5.3.2.1 Impacts of heavy rainfall

- Degrades/erodes crops
- Kills crops
- Maize grows tall, but does not bear fruit (when heavy, consistent rain)
- Can not go to the field, and so crops and weed grow uncontrolled (when heavy, consistent rain)

Heavy rainfall events were all said to impact the farmers' production, by killing, degrading or directly eroding parts or all of the crops, thereby reducing yields. The farmers were unable to establish the exact amount/area/proportion of crops that were ruined, and mostly referred to losing *some, a lot* or *all* crops. Only one farmer, a lady from New Forest, could quantify how her normal yield of four tons of butternut per half a hectare had been reduced to one ton following heavy rainfall in 2009.

During the field visit in the Bushbuckridge area there was one day of very heavy rainfall, 100 mm in less than 24 hours. Having visited some of the wetland fields, where farmers from the western villages farm, prior to the rainfall and then going back after the heavy rainfall there were clear signs of the impact.

**Picture 5.2: Wetland field eroded in heavy rainfall event**

The water had made deep furrows on the hills surrounding the wetland, and one could see how the water had been channelled down the slopes washing away all or large parts of the fields around the bottom of the hill. The river itself was so large that people were having difficulty crossing from one side to the other. Fields close to the river were also badly eroded, while the fields located away from the river and the hill showed hardly any damage at all. The impact thus differs depending on the location of the fields. As came up in one of the focus group discussions, some of the farmers plant next to the river because it is wet and one does not have to carry water. One farmer pointed out the gambling involved though, as one can get good and large crops if planting next to the river, but at the risk of losing it to flooding.

The farmers suggested that consistent rains that are not necessarily heavy enough to cause erosion are not necessarily good either. Rain can actually hinder growth. For example, maize will grow tall but without bearing fruits. Consistent rain also stops the farmers from going to the field, leaving the crops and weeds to grow out of control.



#### 5.3.2.2 Coping and adaptation mechanisms

The coping mechanisms discovered in relation to heavy rainfall are all outlined in the table below. All but one are long-term adaptation mechanisms.

Responses to heavy rainfall was found to be most common among the farmers from the western villages. Table 5.14 below shows all the coping (green) and adaptation (red) mechanisms that came out in the interviews and focus group discussions.

| Coping/adaptation mechanism | Interviews | | Focus group discussions[39] | |
|---|---|---|---|---|
| | Eastern villages (n=23) | Western villages (n=19) | Eastern villages (n=0) | Western villages (n=10) |
| Add soil after erosion | 0 | 1 | 0 | 6 |
| Do mulching | 0 | 0 | 0 | 1 |
| Plough shallow | 0 | 0 | 0 | 4 |
| Locate the field away from the water way | 0 | 1 | 0 | 1 |
| Raise the beds | 0 | 1 | 0 | 1 |
| Build a tank | 0 | 0 | 0 | 1 |
| Build furrow | 1 | 1 | 0 | 4 |
| Make bendy, not straight, furrows | 0 | 1 | 0 | 0 |
| Not cut down natural vegetation/ grow vetiver grass | 0 | 4 | 0 | 6 |
| Grow vegetation in the furrows | 0 | 0 | 0 | 1 |
| Plant early, making the crops strong before the heavy rain | 0 | 0 | 0 | 1 |

**Table 5.14: Number of farmers mentioning the different coping (green) and adaptation (red) mechanisms in response to heavy rainfall.** The table distinguishes between the coping and adaptation mechanisms that were brought out in the interviews and those that were brought out in the focus group discussions.

### Leaving natural vegetation and growing vetiver grass

Leaving the natural vegetation or planting vetiver grass, an adaptation mechanisms used to minimise erosion, is the most common response mentioned by farmers when discussing heavy rainfall. These responses were only made by

[39] Note that only 26 farmers attended the focus group discussions. While all the focus group discussions in the western villages focused on heavy rainfall, none of the focus group discussions in the eastern villages did.

farmers from the *one* western village, namely Motlamogatsane. This can be related to the fact that seven out of the nine farmers that were interviewed in Motlamogatsane had participated in projects AWARD, a local NGO. AWARD had four participatory projects in the village, two of which focused on limiting erosion. So, the farmers in Motlamogatsane learned different farming mechanisms by working with AWARD, one of which is to leave the natural vegetation in the wetland and to plant vetiver grass[40] in the upland, in order to limit erosion caused by heavy rainfall. While the farmers all said that they had learned this adaptation mechanism from AWARD, one farmer told of how she had seen her mother leaving wetland vegetation, but that she never understood why. AWARD taught her about it she said, and she could then understand why her mother had been doing it. So while it does seem like the farmers interviewed in Motlamogatsane have started using this adaptation mechanism after working with the AWARD team, there is thus also evidence that this mechanism was used by farmers further back in time. This illustrates how AWARD was able to develop adaptation mechanisms that build on local knowledge, making the farmers themselves come up with the solutions.

In the other western village, Phelandaba, the farmers did not mention leaving natural wetland plants or growing vetiver grass to deal with heavy rainfall. So at the end of the focus group discussion in Phelandaba farmers were asked if they leave natural vegetation in the wetland, and they replied that they take them out. When they were told about what the farmers from Motlamogatsane do and why, the farmers from Phelandaba said they thought it sounded like a good option and that they would like to try it.

### Adding soil after erosion

Adding soil is the second most common response mentioned, and is a coping mechanism that works to minimise the damage *after* heavy rainfall has taken place. Using soil from the surrounding area, farmers cover crops after erosion, so that that which has survived can keep growing. The coping mechanism was mentioned by farmers from both the western villages.

[40] AWARD supplied them with the initial vetiver grass.

### Building furrows

Building furrows is a more long-term response, and thus an adaptation mechanism, which is used by several of the farmers. The furrows work to control the flow of water and lead it away from the fields, stopping the fields from being washed away. Two farmers stated how they watch the direction of the water when it rains and then build the furrows accordingly. Again, it was only the farmers in Motlamogatsane that described this specific adaptation mechanism, and though it was not specifically said so, it can be deduced that this stems from their work with AWARD.

Building furrows in the wetland that are bendy instead of straight further works to slow the water down, so that it does not flow too easily, washing away the soil in the process. The farmer who outlined this mechanism said that she had learned the method through her work with AWARD.

### Ploughing shallow

Ploughing shallow was also brought up as an adaptation mechanism that had surfaced in the work with AWARD in Motlamogatsane. The adaptation mechanism was not brought up by the farmers in Phelandaba, but when asked whether they had thought about trying to not plough very deep, in order to limit erosion, one farmer confirmed using the method. The farmer said that she had learned the mechanism herself. On the other hand, another farmer said that in order to plant madumbis one has to dig deep or they will not grow. So while not ploughing very deep can be a way by which one can deal with erosion, it is not necessarily an option for all the crops that are grown, and it does not seem like a mechanism used by many of the farmers.

### Locate the field away from the water way

*"When one first looks for a field it is important to keep a distance from the water way."*

(Farmer from western village)

Several farmers from the western villages were found to adapt to the heavy rainfall events by locating their field away from the river in the wetland, so thus minimising the risk of erosion. This also came out in the impacts section, where it was mentioned how planting close to the river, where it is wet, one can get good crops but with the danger of loosing it to flooding. When discussing the use of seasonal forecasts in a focus group discussion, one farmer said that she would farm next to the river if the forecast predicted less than normal rainfall, as the crops would not erode. Thus strategically locating your field close enough to the river to benefit from the moisture, but far enough away to minimise the damage from erosion seems to be one of the strategically important farm management decisions.

Here it should be noted that, as was outlined in the impacts section, fields close to the slopes around the wetland, though not necessarily close to the river, were damaged by erosion after a heavy rainfall event. It therefore seems that it is not only the proximity to the river that impacts the degree of erosion, but also the location of the field in relation to slopes.

**Raising the beds**

Raising the beds is another mechanism by which the farmers from both the western villages were found to adapt to heavy rainfall and flooding events in the wetland. As one farmer argued, if moving your field far from the river is not enough, then you have to raise the beds. While two farmers said that raising the beds is one of the best ways to deal with flooding, farmers in another focus group discussion argued that they have tried raising the beds but that it does not work. So raising the beds seems to be an adaptation mechanism that works to some extent, probably depending on the location of the field and the severity of the flooding.

**Adaptation mechanisms used by progressive farmer**

There is one farmer that stands out among the farmers from the villages without irrigation. She is a farmer who has really used what she was taught through the training in AWARD. Firstly, in order to reduce erosion, she does mulching; an adaptation mechanism that involves leaving a protective cover of for example leaves and grass over the soil. Secondly, in her homestead she used to have problems with erosion from the road, but AWARD helped build her a trench and a tank in her homestead.[41] The tank does not only collect water that enables her to water through parts of the dry season, it also prevents the water from flooding out into her homestead fields. While the tank is a good adaptation strategy, helping both with heavy rainfall and with drought, it seems to only be an option for the rest of the farmers if they obtain the necessary funding.

Lastly, the progressive farmer said that if one ploughs and plants early in the wetland, September, then the crops become strong and survive when the heavy rain comes. While this seems like a good way to make sure the crops cope with the heavy rainfall and flooding, it can be deduced that this method will only be successful if the heavy rainfall and flooding events take place later in the year and if there is enough moisture to get the crops growing.

#### 5.3.2.3 Thresholds

In the focus group discussions the intention was to get some understanding around how much rainfall the fields can withstand before erosion and degradation takes place and the farmers are unable to maintain their farming objectives. While the initial thought was to look at it in terms of the one adaptation mechanism, leaving natural vegetation or growing vetiver gras, it quickly became clear that the impacts from the different mechanisms are inter-related and that it is thus not possible to distinguish between them. In terms of looking at how much rainfall the fields are able to deal with, it was not possible to talk about rainfall in terms of millimetres, as none of the farmers, with the exception of one,[42] have any way to record the rainfall. Discussions were therefore around how many weeks, days or hours it can rain before erosion takes place. As the farmers themselves argued, this depends very much on the type of rain, whether it is heavy or light.

The farmers in the one focus group discussion contradicted themselves a bit. They were first asked whether crops would erode if there is one week of heavy

[41] It seems that the reason why she is the only one in the village who got a tank built by AWARD is that she is the only one who has really been championing their training advice. As a result she has the best homestead garden that the researcher saw in the village, and she produces a wide range of crops, 10 different ones, compared to 7, which is the average among the farmers interviewed in her village.

[42] The progressive farmer who also has a tank, has a gauge that was given to her by AWARD.

rain, and they said no. They were then asked whether there would be erosion after two weeks of heavy rain, and again they said no. Later in the focus group discussion though, they agreed that heavy rain can cause erosion in a day, or even within an hour. In the next two focus group discussions it was again stated that one day of heavy rainfall could be enough to cause erosion.

As was outlined in section 5.3.2.1 on impacts, there was one day of heavy rainfall during the researcher's field visit. From a gauge, owned by the one farmer in Motlamogatsane, it was found that there had been 100 mm of rainfall in 24 hours. As was outlined in the impact section, this rainfall was found to cause flooding and erosion in the wetland, thus confirming the argument that one day of heavy rainfall is enough to cause erosion.

Importantly so, it was also argued that erosion of the crops depends on both the intensity of the rain and the age of the crops. One farmer explained that she planted madumbis late, on November the 5th, and that at the time of the focus group discussion, the 24th of November, the crops were still too young and would thus not do well with the heavy rainfall. This relates to the one coping mechanism outlined above, planting early, making the crops strong before the heavy rain.

So, in terms of dealing with heavy rainfall it was found that one day of heavy rainfall can cause bad erosion and loss of crops for the farmers.[43] What is more, other factors, such as the planting time and thus the age of the crops, were also found to play a role in the degree to which the crops were damaged by heavy rainfall.

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[43] Most of the farmers who engaged in focus group discussions on heavy rainfall farm both in the wetland and in their homestead. While it is not within the scope of this research, it is important to note that subsequent flooding characteristics are very likely to differ between the two locations, as the wetland is down in the lowland by the river and the homestead is in the upland. What can be said though is that most of the statements around flooding and erosion seem to have been linked to the wetland fields. What is more, it seems that more rain is required for there to be erosion in the homestead fields in the upland than in the wetland. This was a point made at the third focus group discussion, which took place after the day with 100 mm of rainfall, when the farmers were asked whether they though the rain on the day before was enough to be characterised as a flood, and the one farmer replied that it would be characterised as a flood in the wetland, but not in the homestead.

### 5.3.3 High temperatures

This research does not apply any specific definition for high temperatures.

#### 5.3.3.1 Impacts of high temperatures

- More insects that eat or destroy crops
- Soil quickly dries after irrigating
- Shortage of water
- Plants become weak or die
- Crops burn in the sun (especially tomato)
- More disease

High temperatures are seen as impacting the farmers' activities and crops in various ways. For example, high temperatures are perceived to bring more insects. The heat also brings more disease, and makes the water evaporate quicker, so the soil quickly becomes dry after irrigating (for those of the farmers with irrigation). Because the farmers in the irrigation schemes irrigate according to a schedule, meaning that they can only use the irrigation water at certain times, it is not easy for them to just irrigate more often. As the farmers in one focus group discussion said, they cannot irrigate more often because there is not enough water and they are all sharing the water. High temperatures are also said to cause shortage of water, presumably due to, among other things, increased evaporation from dams and rivers. Farmers also argued that the heat makes their plants weak, burns them, and also kills them. The farmers were finding that 2010, the year of the interviews and focus groups, was very hot, and a lot of them had lost crops. Visiting their fields, clear evidence was found in rows upon rows of burnt tomatoes.

**Picture 5.3: Tomatoes burning in the sun**

One farmer said that he had lost a whole hectare of tomatoes. Some farmers also said that their cabbages and maize had been burnt by the sun that year, and while one farmer had lost nearly all the cabbages that had been planted, several farmers said that they had lost half of the maize that was planted. Though the high temperature was crucial in their losses, so was seemingly the late onset of summer rainfall. As was argued by the farmers in one of the focus group discussions, the crops would not have died if it had rained, so it was the combination of high temperatures and late onset. Importantly so, it can be assumed that if it had rained, this would have worked to also cool the temperatures.

### 5.3.3.2 Coping and adaptation mechanisms

The majority of responses to high temperatures were made by farmers from the eastern villages. Only one farmer from the western villages mentioned responding to high temperatures. Interestingly so, this is the one farmer in the villages without irrigation who has himself acquired an irrigation system. While it could be a coincidence, it is worth noting that the farmers with irrigation seem to be more concerned with high temperatures than the farmers without irrigation. All the different mechanisms mentioned in relation to high temperatures are outlined in the table below.

| Coping/adaptation mechanism | Interviews | | Focus group discussions[44] | |
|---|---|---|---|---|
| | Eastern villages (n=23) | Western villages (n=19) | Eastern villages (n=16) | Western villages (n=0) |
| Irrigate/irrigate in the morning and evening/avoid irrigating in the day when the water is hot/irrigate more often | 2 | 0 | 6 | 0 |
| Weed in the morning | 0 | 0 | 1 | 0 |
| Delay or shift the planting season | 2 | 0 | 0 | 0 |
| Leave grass between the tomato plants | 1 | 0 | 0 | 0 |
| Do mulching | 0 | 1 | 0 | 0 |
| Use sprays | 2 | 0 | 7 | 0 |
| Nothing to do – can not afford buying nets/build greenhouse | 1 | 0 | 7 | 0 |

**Table 5.15: Number of farmers mentioning the different coping (green) and adaptation (red) mechanisms in response to high temperatures.** The table distinguishes between the coping and adaptation mechanisms that were brought out in the interviews and those that were brought out in the focus group discussions.

Many of the responses to high temperatures are related to irrigation. While some farmers simply said that they deal with high temperatures by irrigating, other farmers were more specific, saying that when there are high temperatures it is better to irrigate in the morning or in the evening. In the daytime the evaporation rates are higher, and so a smaller proportion of the water used will actually benefit the crops. On the other hand, one farmer mentioned how it is not good to irrigate during the day when the water is hot. The warm water is not good for the roots, and will shock the plants.

In the initial interviews two farmers say that they irrigate more often in order to deal with high temperatures. In one of the focus group discussions though, it was

[44] Note that only 26 farmers attended the focus group discussions. While all the focus group discussions in the western villages focused on heavy rainfall, none of the focus groups in the eastern villages did.

stated that they cannot irrigate more often because they are all sharing the water. In another focus group discussion, when the farmers were asked whether they irrigate more often when it is very hot, they simply answered that they irrigate one day, then there are three days before they can irrigate again, following the schedule made in the irrigation scheme. As was mentioned in the section looking at the delayed onset of summer rainfall, water issues create friction between some of the farmers. So it seems that, while the farmers would like to irrigate more often when it is very hot, most of them do not due to the fact that there is just not enough water for everyone to do so.

The use of various sprays was also mentioned in relation to high temperatures. Some farmers argued that they use sprays to protect the crops from the sun and the heat, using for example what they called Copper and Dithane. Other farmers stated that sprays are used to deal with insects, and not with the sun. This was confirmed by staff at the Koöperasie, the farmer supplies shop, where they showed how for example Dithane deals with different fungi, disease and insects. One farmer stated how high temperatures lead to more insects, and that therefore he has to use insecticides. The farmer also said that he constantly has to change the insecticides, as the insects adapt to them. So while some of the farmers seem to think that the sprays directly protect the plants from the sun and the heat,[45] others see that the sprays work to deal with insects and disease that potentially come about because of the sun and the heat. Using sprays is not an adaptation mechanism available to everyone though. As one farmer stated in the interviews, he would like to use sprays but cannot afford it.

Delaying or shifting the planting season, a coping mechanism very common in response to delayed onset of summer rainfall, was also mentioned as a way to cope with high temperatures. One farmer argued that maize cannot grow at temperatures over 34°C, and so they are better to plant in the winter, March,



45 Note that this could also potentially be a misunderstanding that came about through the translation, and so it is not impossible that these farmers also understand that the sprays are not directly protecting the plants form heat and sun.

April, May.[46] Delaying, or simply shifting the planting season, is thus another way by which some of the farmers cope with high temperatures.

One farmer also told how he, around 2005, started leaving some grass between the plants to prevent them from burning in the sun. A side effect of this is that he has had to change the way he feeds his crops, using more fertilizer as the grass too feeds on the fertilizer. Another farmer said that he would like to start mulching, putting for example grass and leaves on top to protect the plants,[47] but that he does not have the time at the moment. A third farmer said that he only weeds in the morning, after which it is very hot, and so not very good for the plants. The farmer says that it is better to weed when the soil is cool and moist.

Lastly, several farmers said that they cannot afford to buy nets to protect the crops from the sun and the heat, and so there is nothing they can do to deal with the high temperatures. The participants at two focus group discussions said that the best way to deal with high temperatures is to get nets. One farmer also mentions that building a greenhouse could also be a solution, but that again, this is not affordable. So several of the farmers seem to feel incapable of finding mechanisms that allow them to deal with the high temperatures.

Considering all the coping and adaptation mechanisms outlined above, the important points that should be made include the fact that there are several mechanisms that are only partly or not at all accessible to the farmers, namely irrigating more often, using sprays and buying nets.

#### 5.3.3.3 Thresholds

Five focus group discussions focused on trying to establish a coping range for temperatures, featuring discussions around the temperatures that the crops are unable to cope with. It should here be noted that the farmers are not able to measure temperatures, and so their observations are largely based upon perceptions, potentially together with weather forecasts from TV and radio.

[46] The large majority of the farmers in the eastern villages also grow crops in the winter season, while only a small portion of the farmers in the western do (mainly because there is no rainfall in the winter).

[47] Note that this is how he explained the mulching, and it can be deduced that the mulching protects the crops by retaining the moisture in the soil

When discussing temperatures and crops in general it was in one focus group discussion stated that 28 degrees Celsius is cool, while in another focus group stated that 28-29 degrees Celsius is not good. At the latter focus group they also argued that crops will not survive even three days of 32 degrees Celsius. At that same focus group discussion it was also stated that crops can survive one very hot day a week in December, but only if it has rained just before the heat sets in or if they are able to irrigate. At another focus group discussion they stated that 39 to 42 degrees Celsius is bad, and that the crops would also burn at 38 degrees Celsius, even if one irrigates. Based on these statements it seems that temperatures over 30 degrees Celsius are not good. While it seems that rainfall or irrigation can keep the crops alive when the temperatures are just over 30 degrees Celsius, this is not necessarily the case when temperatures get close to 40 degrees Celsius.

According to one of the extension officers that was interviewed, the Bushbuckridge area would usually not experience more than 40 degrees Celsius, but they are now experiencing up to 40-44 degrees Celsius, which is not good for crops. A man working with MABEDI, the development initiative operating in the eastern villages, said that a two degrees increase from the current average temperatures would be very bad for the crops, and that a lot of skills and funding would be necessary for the farmers to handle that. Section 5.4, on future projections, show that projections actually indicate a two-degree increase in average temperatures by the middle of this century.

When discussing tomatoes, participants at two focus group discussions said that tomatoes grow well when it is not too warm and not too cold. It was also said that the tomatoes are delicate, and so cannot handle three hot days of about 39 to 42 degrees Celsius. At one focus group discussion, participants said that tomatoes die already when temperatures start hitting over 35 degrees Celsius. The statements of the focus group discussion participants do not correspond well with those of an extension officer, who says that tomatoes grow well in 36 to 38 degrees Celsius. If taking a look at the historical data for the period 1960 to 1999 it can be found that the highest average monthly temperature is 32.6 (January). So while this does not mean that the area does not experience temperatures of around 40 degrees Celsius, it indicates that the extension officer is wrong when stating that the area generally experiences 36 – 38 degrees Celsius. It is possible that the extension officer was meaning to say 26 – 28 degrees Celsius, which makes more sense when looking at the other statements and the historical records. For tomatoes, it is difficult to make any conclusions, but it can be found that, if one excludes the statements from the extension officer, that tomatoes start struggling as temperatures start going above 30 degrees Celsius, and that 40 degrees Celsius and up is not good for tomatoes. This corresponds somewhat with findings from a study on heat stress in tomatoes, which found that the ripening of tomatoes is delayed by several days if they are exposed to one day of 42 degrees Celsius (Iwahashi et al., 1999).

Based on farmers' own perceptions, it is difficult to set any temperature thresholds beyond which the farmers are not able to farm as usual and all or a large proportion of the crops are likely to die. What can be said though is that first of all it seems that temperature is not a stressor that can be evaluated in solitude. Other factors, more specifically rainfall and irrigation, seem to play an intricate role in the impact experienced due to high temperatures. If it rains or the farmers are able to irrigate enough, then it seems that the crops are more likely to survive, though it is here unclear what is actually enough. Second, it can be said that it seems that the crops can manage relatively well at around 30 degrees Celsius, if they receive enough water, and that temperatures of around 40 degrees Celsius are problematic, even when the crops are watered enough. The last point that is important to note is the fact that, according to a man working at MABEDI, a two degree increase from the current average temperatures would be very bad for the agricultural activity in the area.

#### 5.3.4 Crop losses

Having looked at the mechanisms that the farmers use to try and protect their crops and harvests from different climatic stressors it is clear that they are not always able to. It is therefore important to have a look at what they do when they experience reduction in yields. The following list outlines the different mechanisms that are used in order to farm again the following season, after farmers have lost crops and income.

- Use money from pensions
- Use money from children's grants
- Use money from off-farm employment
- Receive help from other farmers
- Receive seeds from MABEDI
- Plant smaller area

In one focus group discussion farmers started talking about how they had lost crops that they had planted for the 2010 summer season, due to a combination of high temperatures and a late onset. They said that they were losing money, and that it would therefore be difficult to get money for planting next season. So when asked how they would actually be able to buy seeds and fertilizers to plant the following year, one farmer said that she would save the money from the child grants in order to get started next season. In another focus group discussion the farmers said that if a person in the household works or has a pension then they live off that. As one of the farmers said, she has someone in the house that is working and thereby they survive, though it is still difficult. Other mechanisms include helping each other, that those who have lost less crops will help those who lost a lot. Farmers also mention that they sometimes receive seeds from MABEDI, which helps them to plant again after a bad season.

Another coping mechanism mentioned is to plant a smaller area the following season. Two farmers in one of the focus group discussions said that, after losses they had experienced in 2010, they will use the little money they have to plant in the next season, but that it will be a smaller area than what they usually plant. This mechanism has also been mentioned as a coping mechanism that the farmers use to limit the impact of a delay in the onset of the summer rainfall. As it was brought out here though, by these two farmers, it was used as a way to cope with crop and income losses from the previous season.

It thus seems that when farmers have lost all or a large portion of their crops due to some climatic or non-climatic stressor, they sometimes have to plant a smaller area the following season, but they also have to fall back on government grants, money from off-farm employment or on help from other farmers or initiatives like MABEDI. Interestingly so, as was pointed out by an official from MABEDI[48], the farmers from the irrigation schemes in the eastern villages used to be subsidised by the government. So in the case of crop failures then the government would come in and subsidise their next planting season. This is no longer the case though, and the farmers now have to manage by themselves.

## 5.4 Localised future projections

*Assessing what the local climate in Bushbuckridge is projected to look like into the future, and how the farmers are likely to be impacted by projected climate change*

The purpose of this section is to get an understanding of how the climate in Bushbuckridge might change into the future. The analysis includes mean monthly rainfall, rain-days with over 50 mm of rainfall, mean monthly rainfall variability, mean monthly maximum temperatures, days with maximum temperatures of over 40 degrees Celsius and mean monthly maximum temperature variability. The analysis uses downscaled climate change projections from a number of GCMs, for three stations in Bushbuckridge and the wider area. The projections are based on the A2, business as usual, emission scenario, and consider both the near future, 2046 to 2065, and the distant future, 2081 to 2100. The focus here is on the rainy season, September to April,[49] in particular, as this is the main planting season for farmers in the area.[50]

### 5.4.1 Mean monthly rainfall

Water availability is a crucial factor in farming activities, and changes in the mean monthly rainfall during the rainy season could impact the availability of water. For monthly rainfall projections the analysis only considers the agreement on direction of change, not the magnitude of change, due to the large spread found in the downscaled Global GCM outputs.



[49] This is a relatively broad definition of their rainy season, (the rain most commonly starts in October, and the large majority of the rain falls from November to the end of February) but has been included in order to detect potential shifts in the season.
[50] Though some farmers, mainly those with irrigation, also farm during the dry season.

| Month | Near Future (2046-2065) | Distant future (2081-2100) |
|---|---|---|
| September | Wetting | Wetting |
| October | No agreement on direction of change | Wetting |
| November | Wetting | Wetting |
| December | Drying | Drying |
| January | No agreement on direction of change | Drying |
| February | No agreement on direction of change | Drying |
| March | No agreement on direction of change | Drying |
| April | Wetting | No agreement on direction of change |
| May | Wetting | Wetting |
| Annual | Wetting | Wetting |

**Table 5.16: Projected direction of change for mean monthly rainfall.** The table presents the months during the rainy season in which the median rainfall anomaly for all three stations agree on the direction of change.[51]



For the distant future the projections indicate drying in the middle of the rainy season, from December to the end of March, in the period where the majority of rainfall usually falls. For the start and the end of the rainy season, on the other hand, there are indications of wetting, both in the near and the distant future. The indications of wetting in the mean annual rainfall reflects how overall the rainfall is not projected do decrease.

### 5.4.2 Rain-days with over 50 mm of rainfall

Many of the farmers in Bushbuckridge were found to have problems with erosion due to heavy rainfall. A look at change in heavy rainfall events, by considering days with over 50 mm of rainfall, creates an indication of whether farmers need to prepare themselves for more such events in the future.

[51] See methodology for further details.

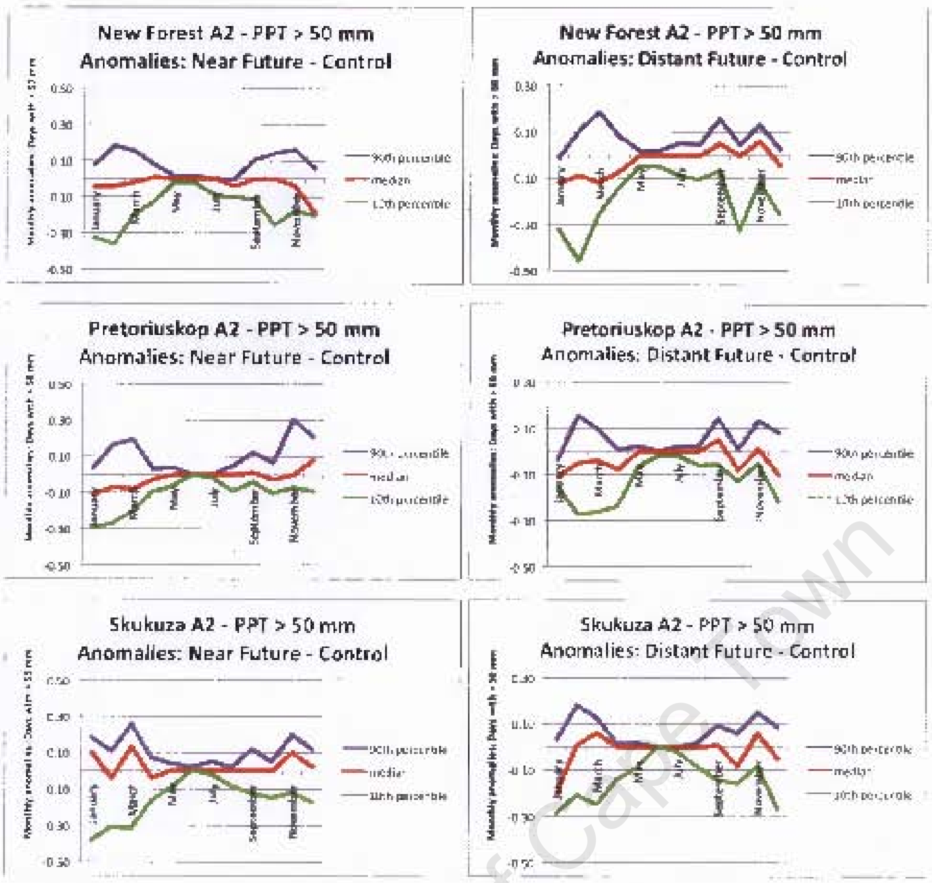


**Figure 5.8: Projected anomaly in the mean monthly number of days with rainfall over 50 mm for the near (left) and distant (right) future.** The projections are based on the anomalies from seven downscaled GCMs for each station, and the graphs represent the median, 90th and 10th percentile.



The median of the projections for the near future at all three stations indicate that the number of heavy rainfall events is likely to decrease in February, with no agreement on changes in other months. For the projections for the distant future all three stations agree that the number of heavy rainfall events will decrease in December and January, and increase in September and November.

For the near future the projections therefore don't show any concerning trends with regard to heavy rainfall events. For the distant future, projections show an increase in heavy rainfall events in September and November, and this could have negative effects. Still, the projected changes are so minor, with median change of less than half a day a month, that they are unlikely to create additional challenges for farmers.

### 5.4.3 Mean monthly rainfall variability

When investigating the historical records in section 5.1 of this research work, it was found that farmers in the Bushbuckridge area are currently experiencing some variability in the mean monthly rainfall during the rainy season, with percentage standard deviations ranging from 40 to 90%. Variability in rainfall can create challenges for farmers, as it becomes more difficult to plan for planting times and the types of crops that should be planted.

Analysis of changes to the mean monthly rainfall variability found that there were no consistent signs of increase or decrease for any months in the year. The analysis compared the percentage standard deviation for the mean monthly rainfall for the control period with the percentage standard deviation for the mean monthly rainfall for the near and the distant future period. This was done for each of the seven downscaled GCM outputs, for each of the three stations. The number of downscaled GCM outputs showing increase or decrease in the percentage standard deviations was compiled, making it possible to compare the number of GCMs showing increase or decrease in variability at each station. Considering only the cases where a minimum of six out of seven models agreed on the direction of change, there were very few cases where a station showed agreement around the direction of change. There were no cases where the three stations agreed on the direction of change.



As these projections show little agreement in the downscaled GCM outputs, they do not provide any clear indication of whether the monthly rainfall variability is likely to increase or decrease into the future.

### 5.4.4 Mean monthly temperatures

Some of the farmers in Bushbuckridge were found to struggle with impacts from high temperatures, and have few ways to protect crops from the heat and the sun. Changes in mean monthly temperatures are analysed here in order to get an indication of whether farmers might have to deal with even higher mean temperatures in the future.[52] Accordingly, the graphs in figure 5.9 below outline the mean maximum temperature anomalies for the near and the distant future.

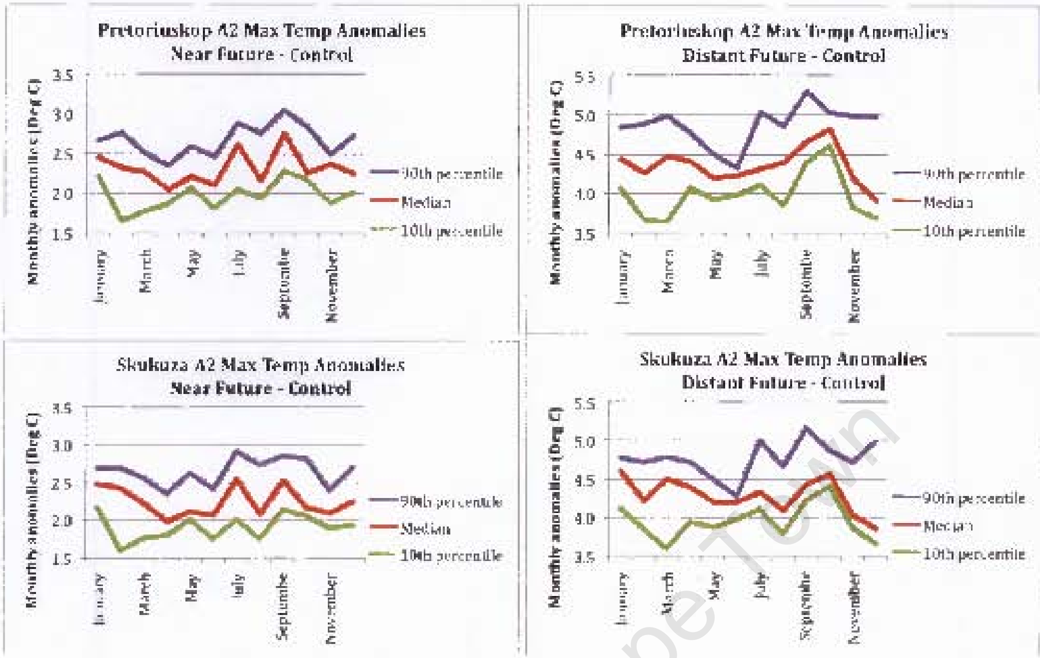


**Figure 5.9: Projected anomaly in the mean monthly maximum temperature for the near (left) and the distant (right) future.** The projections are based on the monthly anomalies from seven downscaled GCMs for each station, and the graphs represent the median, 90th and 10th percentile.

The temperature projections are fairly uniform, indicating increases of around two degrees through the year for the near future and increases of around four degrees for the distant future. These are considerable increases, and could require quite substantial changes to current farming practices. Temperature increases peak in September in the near future and October in the distant future, which could be particularly negative for farming practices as this is a time when farmers plough and plant.

### 5.4.5 Number of days with maximum temperatures over 40 degrees Celsius

Farmers in Bushbuckridge indicated that when temperatures hit 40 degrees Celsius it is difficult to keep crops alive and healthy, even when they have access to sufficient water. This section therefore looks into the changes in the mean monthly number of days with over 40 degrees Celsius. Accordingly, the graphs in

[52] Note that for temperatures projections data is only available for two of the stations, namely Pretoriuskop and Skukuza.

figure 5.10 below outline the changes in the mean monthly days with temperatures over 40 degrees for the near and the distant future.

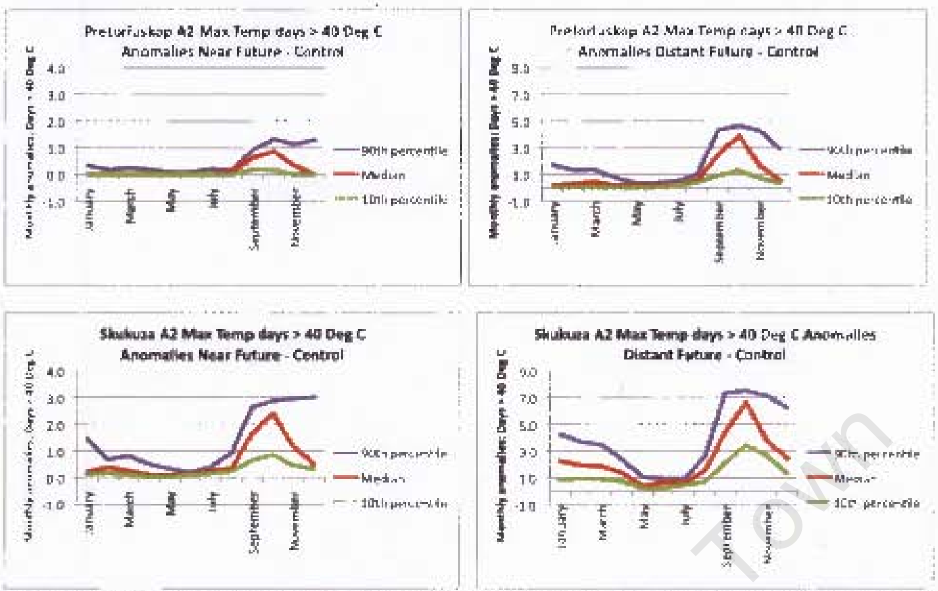


**Figure 5.10: Projected anomaly in the mean monthly number of days with maximum temperatures of over 40 degrees Celsius for the near (left) and distant (right) future.** The projections are based on the monthly anomalies from seven downscaled GCMs for each station, and the graphs represent the median, 90th and 10th percentile.

For the mean monthly number of days with over 40 degrees Celsius there are indications of slight increase through the whole year. The only significant increase can be seen in September through December, peaking in October, in both the near and the distant future. As for the increases in mean monthly temperatures, the most significant increases are projected for months that are very important in agriculture, the months when ploughing and planting take place.

### 5.4.6 Mean monthly maximum temperature variability

The investigation of historical records in section 5.1 of this paper found that mean monthly maximum temperatures currently have very little variability from year to year, with standard deviations ranging from around 0,61 (annually), to a max of 1,85 (Skukuza, February). An increase in mean monthly maximum temperatures could create challenges similar to those outlined in relation to variability in rainfall.

Analysis of changes in the mean monthly maximum temperature variability showed very little consistency in the signs towards increase or decrease. The analysis was conducted in the same way as for the analysis of variability in rainfall (see section 6.4.3), but using data from two stations, Pretoriuskop and Skukuza, only.[53] Agreement in the downscaled GCM outputs and across the two stations was only found for one month and one time period, namely for May in the near future. At Pretoriuskop seven out of seven downscaled GCM outputs show an increase in the variability in mean monthly maximum temperatures in May in the near future, and at Skukuza six out of seven downscaled GCM outputs show an increase in May in the near future.

Projections can therefore be found to show little agreement on changes to the variability in mean monthly maximum temperatures, agreeing only on an increase in variability in the month of May in the near future.

### 5.4.7 Comparing GCM outputs and downscaled GCM outputs

Having analysed the downscaled projections it is important to keep in mind that these are based on downscaled data for three, and in some cases two, stations only. While this is intentional, as the aim is for the projections to be as localised as possible, they should also be used with caution given that they are based on such a limited number of stations. It is therefore good to compare them with GCM projections for the area, and see how well they correspond.

The GCM scale projections reflected in the figure (map) below do not correspond very well with the downscaled projections outlined above. For example wetting indicated for the start of the rainy season can only be seen if considering the 75$^{th}$ percentile, while the median indicates a slight drying. In the middle of the rainy season, for which the downscaled projections indicate drying (in December in the near Future), the GCM scale projections show drying only if considering the 25$^{th}$ percentile. The lack of correspondence between the GCM outputs and the downscaled GCM outputs could be related to a number of factors, including the use of slightly different GCMs, the very location specific nature of rainfall or the way that that downscaled projections were analysed compared to the way the

[53] As the third station, New Forest, does not have temperature data.

GCM projections were presented. At the same time it highlights the fact that rainfall tends to be poorly captured in projections (Challinor et al., 2007; Speranza, 2010), and that these projections should be used carefully.

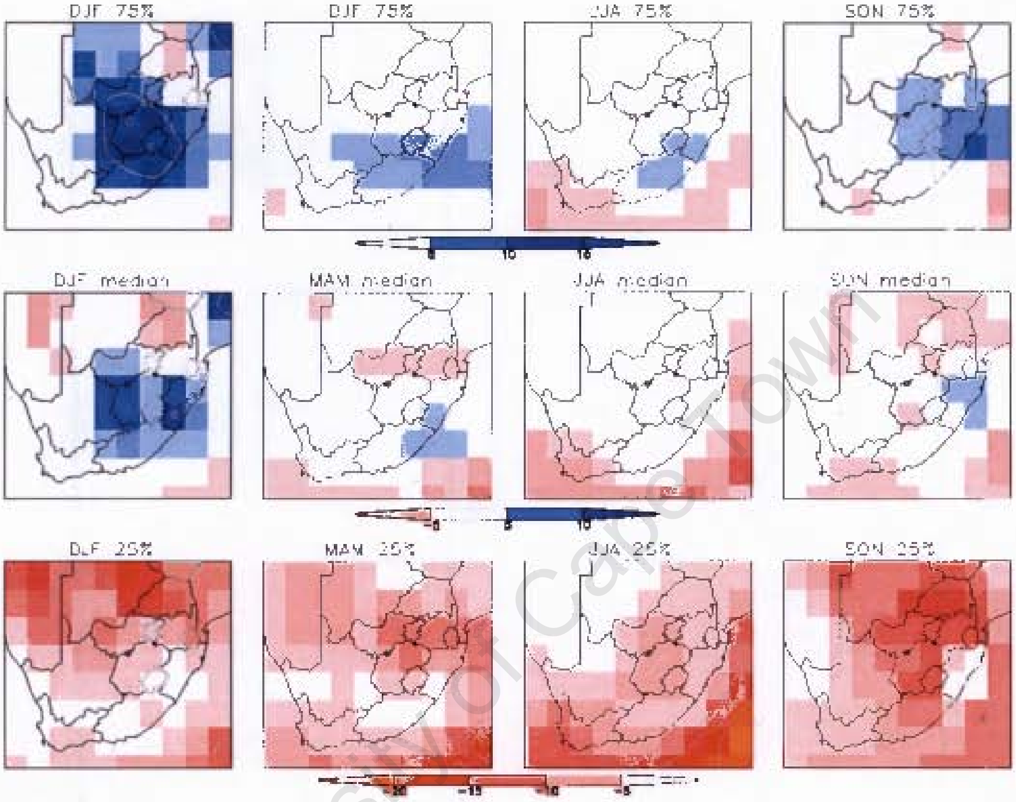




**Figure 5.11: Projected change in average monthly total rainfall (mm/month) from ten GCMs.** The anomalies represent the difference between 2046-2065 (the near future) and 1961-2000 (control period), based on the A2 emission scenario. The rows represent the 75th percentile (top), median (middle) and the 25th percentile (bottom), while the columns each represent a three month season of the year. (Source: Tadross et al., 2011)

For temperatures the projections correspond better, indicating a median increase of about 2 degrees through the whole year in both the downscaled and GCM scale projections, as can be observed in figure 5.12 below.

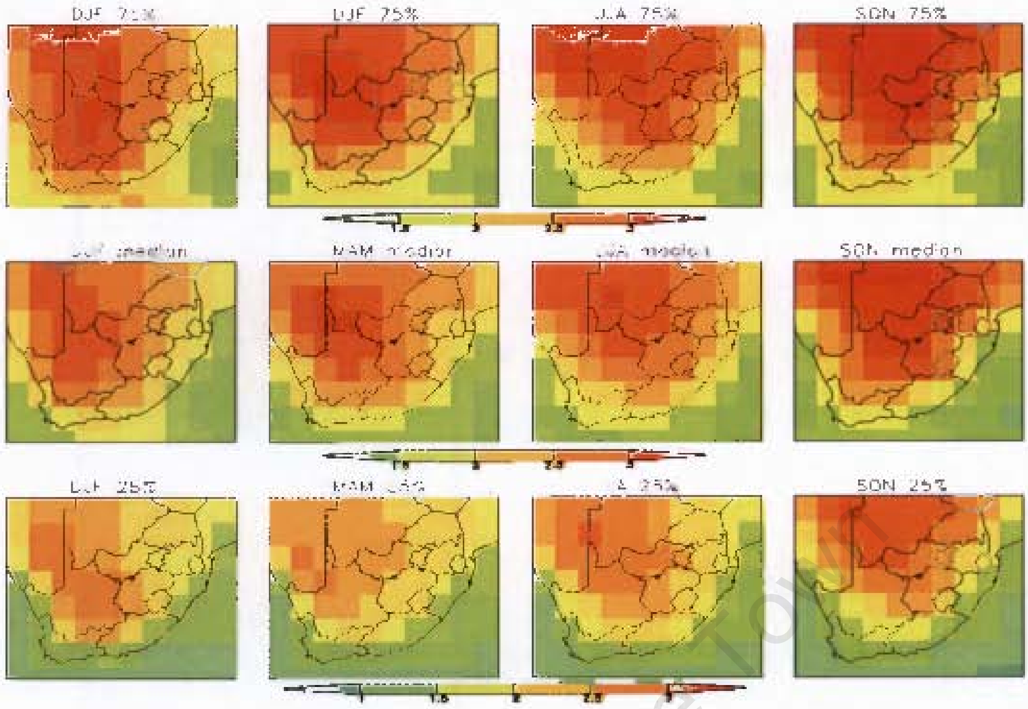

**Figure 5.12: Projected change in average surface air temperature (°C) from ten GCMs.** The anomalies represent the difference between 2046-2065 (the near future) and 1961-2000 (control period), based on the A2 emission scenario. The rows represent the 75th percentile (top), median (middle) and the 25th percentile (bottom), while the columns each represent a three month season of the year. (Source: Tadross et al., 2011)

# 6. Discussion

This section brings together the results emerging from the research conducted in Bushbuckridge. The discussion has brought together six main themes, including perception of change, the complexity and communitity specific nature of vulnerability , the current lack of capacity to cope and adapt, the inter-related nature of stressors and responses, the limitations challenging training and support and the need for additional adaptation in response to future projections.

## 6.1 Perceiving change –a step towards adaptive behaviour

Farmers in Bushbuckridge have some understanding of the current climate, which is an important step towards adapting to climate change. The data presented illustrates how farmers perceive both a general inter-annual variability in the timing of the onset of the summer rainfall, as well as variability in the inter-annual rainfall, perceptions that were confirmed in the historical climate data from local stations. Some farmers also perceive variability in temperatures, but this variability could not be confirmed when considering mean monthly temperature records.[54]

With regard to trends of change, farmers perceive both a shift towards a later timing of the onset of summer rainfall, as well as a decrease in annual rainfall, and increasing temperatures. These trends were all detected in the historical data to some extent. With regards to rainfall, drying was, most importantly so, detected for November, January and February, while for temperatures there were statistically significant trends of increase in minimum temperatures for all months of the year except August. Some of these changes also correspond with the findings in a study by Gbetibouo (2009), where a trend was established based on the mean of all the stations in Mpumalanga. Considering the period 1960 to 2003 Gbetibouo (2009) found that mean temperatures have increased by 1,83 degrees Celsius and precipitation has decreased by nearly 38 percent.

For heavy rainfall events there was found to be some correspondence between historical records and perceptions, but the analysis was somewhat limited due to

[54] The analysis only considered monthly temperature means, and so does not exclude that there is more variability in the temperatures from day-to-day.

lack of recent historical data and appropriate methodology for detecting extreme events. What should be highlighted, is the fact that farmers commonly recalled heavy rainfall events, while only a few mentioned extreme temperature events. This corresponds with the findings in the vulnerability analysis, where it was found that farmers are a lot more exposed to heavy rainfall events than they are to droughts.

Some literature has suggested that farmers need to notice that the climate has changed in order to identify and implement useful adaptation (Maddison, 2006; Gbetibouo, 2009). In Bushbuckridge farmers' recognition of change can thus be seen as an initial step towards changing behaviour, which is crucial seeing that their perceptions of change can be confirmed in historical data. What is more, as Maddison (2006) argues, it might take time for farmers to see whether changes in the weather are permanent. The recognition of a permanent shift is necessary if farmers are to engage in forward looking behaviour, rather than working with backward experiences (Maddison, 2006).

## 6.2 Vulnerability – Complex and community specific

The results from the vulnerability analysis show that vulnerability is complex, shaped by multiple stressors, underlying factors and inter-linkages, and that it is played out differently among different communities. These are important findings for activities that aim to support adaptation action or reduce vulnerability.

### Multiple stressors shape the vulnerability of farmers

As has been highlighted in various literature, climatic stress is only one of the many factors that shape the livelihoods and the resilience of farmers (Morton, 2007; Thomas et al., 2007; Ziervogel and Taylor, 2008; Casale et al., 2009; Ghetibouo and Ringler, 2009; Mertz et al., 2009). A good example that came out from the research in Bushbuckridge is in relation to water scarcity, the most common problem identified amongst the farmers interviewed. This example reflects how vulnerability to what is seemingly a water scarcity problem can be shaped by underlying factors, such as political decision-making and financial capacity. The nature of the problem is somewhat different in the western and the eastern villages, and the problems of water scarcity thus also reflect the very different context in which the farmers from the eastern and the western villages live and work.

The research in Bushbuckridge also exposes other factors that shape vulnerabilities. For example, the lack of markets for tomatoes in the eastern villages, following the shut down of a local tomato jam factory, reflects farmers' vulnerability to market forces. Lack of financial capacity is another example, which is the reason why farmers from the western villages can not buy fences, making them vulnerable to livestock that eat and trample all over their crops.[55] These examples also reflect differences between the eastern and the western villages. First, as opposed to the eastern villages, tomatoes are not very common among the crops grown by farmers from the western villages, and so in the western villages farmers never mentioned problems related to tomato sales. Second, as opposed to farmers from the western villages, farmers from the eastern villages did not mention livestock eating and destroying crops as a common problem.

These are examples of farmers' exposure to multiple conditions and factors that shape vulnerabilities. They show how farmers in rural areas are influenced by processes at different scales, from political decision making, to changes in the market, and to fencing and livestock issues at the local scale. The findings support a common argument made in literature, that farming is impacted by multiple factors, including economic, political, social and physical (Morton, 2007; Meinke et al., 2006; Risbey et al., 1999; O'Brien et al., 2004b; Smit and Skinner, 2002). The findings further support the notion that climate change adaptation in agriculture has a complexity that requires multidisciplinary approaches (Howden et al., 2007).

These examples from Bushbuckridge also illustrate how exposures and conditions that shape vulnerabilities can be community specific. The differences between the eastern and the western villages thus support the findings made in previous studies, which have argued that vulnerability is location specific (Smit and Wandel, 2006; Casale et al., 2009; Ziervogel et al., 2006a).

[55] While recognising that this might also be related to cultural aspects, and the village norms related to grazing, such factors are not the focus of this research.

**Investigating the context of vulnerability indicators - uncovering underlying factors and inter-linkages**

The vulnerability analysis was based on the Turner et al. (2003a) framework, which builds on three main components, namely exposure, sensitivity and resilience. In the analysis exposure to climatic stressors was considered across the farmers from the eastern and the western villages together, due to lack of separate data, and the differences between the two locations thus lay within the indicators of sensitivity and resilience. Using a set of three sensitivity and seven resilience indicators the analysis found that farmers from the western villages are more sensitive and less resilient than the farmers from the eastern villages. At the outset of the study, the farmers from the eastern villages were known to be less sensitive than those from the western villages, because of their access to irrigation, and more resilient in that they have the support structure found in a farm organisation like the irrigation scheme. These differences were the reason why the four villages were initially grouped into the western and the eastern villages.

With regards to why the villages score differently for the various indicators, the loss of crops due to extreme events can for example be related to their different farming systems. The farmers from the eastern villages farm with irrigation systems and are thus less sensitive than the farmers from the western villages to variability in rainfall. It could also be related to the location of their fields, with the farmers from the eastern villages farming in the upland and the farmers from the western villages having fields down in the wetland, which seem to be more prone to flooding and erosion.

For the resilience indicators where the western villages scored best, namely the proportion of households that have one or more family members with off-farm employment and the proportion of the households receiving monthly government grants, the difference between the villages are quite significant, over 30%. While it can be difficult to locate the reasons why these are quite distinct differences, it can be theorised that because the agricultural activity in the eastern villages is generally larger in scale and closer to a commercial level than in the western villages, more time and labour is needed to keep those activities going. There is thus in the eastern villages less time and energy to be spent on off-farm employment than in the western villages. As for social grants, no apparent reason seems obvious. For example, the difference in the average age of those interviewed is not significant enough to indicate that more farmers from the western villages should be accessing old age pensions. The role and importance of government grants will be discussed in further detail in the section on different coping and adaptation mechanisms.

The vulnerability analysis, which compares locations that are a mere 40 minutes drive apart, thus further supports the argument that vulnerability is location specific, even within very small spatial scales. As was highlighted by Ziervogel et al. (2006a), vulnerabilities can also differ down to the scale of households or groups within communities. In order to understand whether the interpretation of the different indicators creates a good picture of the differences between the eastern and the western villages it is important to discuss some of the indicators in more detail.

*Irrigation*

Various literature has been found to support irrigation as making farmers less sensitive to for example drought and climate variability (Wilhelmi and Wilhite, 2002; O'Brien et al., 2004b; Gbetibouo, 2009). When using irrigation as an indicator it is also important to look at the type and state of the irrigation system. The farmers from the eastern villages all work with a flood irrigation system, meaning that the water is transported from dams into large canals and on into smaller canals from which the farmers then channel the water into their field. The irrigation systems are old, built in the 1960s, and the farmers told of numerous problems such as broken canals, silted dams, broken valves and lack of human and financial resources to deal with the problems. Given this old and unreliable irrigation system, the farmers from the eastern villages can still be considered vulnerable in the context of water access. While they do not have to rely on rainfall to the same extent as the farmers from the western villages, they cannot be seen as experiencing a stable and reliable access to water. In a vulnerability analysis, the degree to which an irrigation system is considered to reduce someone's sensitivity should therefore be related to the functionality of the system.

Here it is also worth noting that the large majority of farmers from the western villages do a great portion of their farming in wetlands. The wetlands are generally wet, and a river provides farmers with access to water. This further illustrates how irrigation is not the only mechanism that can potentially make farmers less sensitive to climate variability and extreme weather events.

*Crop damage from extreme events*

When investigating crop damage from extreme events it can also be important to look at the type of extreme events that cause the most impact. As was outlined in table 5.11 in section 5.3, heavy rainfall is overall the most common extreme event mentioned, though only twice causing a loss of all crops. The second most common extreme event mentioned is drought. For droughts, on the other hand, six events are mentioned where all crops were lost. Farmers' recollection of events and losses therefore indicates that while heavy rainfall is by far the most common extreme event in the area, drought tends to cause more severe damage to crop yields. So while the farmers are more frequently experiencing losses due to heavy rain, droughts, though less frequent, seem to cause a greater impact.

*Access to insurance*

As came out in the vulnerability indicators, none of the farmers interviewed have insurance. What the indicator fails to highlight, is why. As argued by O'Brien et al. (2009), rather than only focusing on the outcome, there should be focus on changing the underlying reasons. Interviews with farmers in Bushbuckridge therefore included questions that investigated whether the interviewees had heard about insurance options, and further why those who have heard about insurance have not acquired it.

Only 12 farmers were found to have heard about insurance. Out of those 12 farmers 11 are from the eastern villages, showing a very distinctive difference between the two locations. The farmers from the eastern villages had heard about insurance through the chairperson in the irrigation scheme, through extension officers or other government officials, by listening to the radio, by word of mouth or by representatives coming to the irrigation scheme to inform them. It can therefore be found that the farmers from the eastern villages have much greater exposure to information, through the interaction that takes place in their irrigation schemes, than the farmers from the western villages.

The 12 farmers who had heard about insurance were also asked why they have not made use of any insurance options. While one farmer said that insurance is not yet accessible in the area where he farms, six of the farmers argued that they can either not afford it or that their land and yield is too small to insure. Other statements include: when one does not own the land it is only possible to get insurance as a group, with other farmers; it is not possible to insure when the irrigation system is so bad; and insurance is not necessary.

So while the main reason that none of the farmers across the eastern and the western villages have insurance seems to be that the majority do not know about it, the main barrier amongst those who do know about it seems to be that they do not think they can afford it or that they are not eligible. Importantly so, through the interaction that takes place at the irrigation schemes, the farmers from the eastern villages were found to have much better access to information about insurance than the farmers from the western villages. Knowing about insurance is a first step towards acquiring it, but farmers also need further information in order to understand how it works. As previous research has shown, those who understand insurance are more likely to desire to purchase it (Patt et al., 2010).



While this study sees access to insurance as strengthening the resilience of farmers, it is important to note that this is not always the case. For example, unreliable insurers or high insurance premiums can create challenges for farmers, who end up loosing money rather than experiencing a reliable safety net.

*Access to credit*

Access to credit is another indicator that should be looked at in more detail. As was shown in the indicator, four farmers from the eastern villages and two farmers from the western villages have at some point taken up a loan. Here it is further worth noting that three quarters of the farmers said that they know that it is possible to borrow money. The main reason why the majority have not chosen to do so, is that they are worried that they will not be able to pay the money back. Other reasons include thinking that they do not qualify, not trusting the bank, not wanting to pay interest, not wanting trouble or simply not wanting to borrow money.

For the four farmers from the eastern villages who have accessed credit, one did so through Capitec, while one did it though Women's Development Businesses (WDB) and the last two did it through MABEDI. In the western villages both farmers accessed their credit through WDB, borrowing money in order to set up some form of micro business for buying and selling different items. This illustrates how the farmers from the eastern villages, the farmers in irrigation schemes, seem to have a broader exposure to different lending institutions.

This can be confirmed if looking at what the farmers know about the options they have for acquiring credit. While the large majority of the farmers in both groups know that it is possible to borrow money, the farmers from the western villages could not mention any financial institutions. In the eastern villages the farmers were able to mention several, including the Landbank, Nedbank, Capitech, ABSA Bank and MABEDI.[56] The farmers from the eastern villages had been informed either by extension officers or by representatives from the institutions coming to the irrigation scheme.

So, as for insurance, it can be found that farmers from the eastern villages have much greater exposure to information than the farmers from the western villages, due to the interaction that takes place at the irrigation schemes. Accordingly, it can be theorised that with the farmers from the eastern villages being more exposed to detailed information than the western villages, the farmers from the eastern villages more likely to acquire credit in the future.

[56] MABEDI does not actually lend the money out themselves, but link farmers up with financial institutions like the Landbank. In this case the two farmers were not sure of which financial institutions they were borrowing from, but the loans had been set up through MABEDI.

Here it is important to note that while this study sees access to credit as a positive contribution to the resilience of the farmers, there could also be a reverse relationship. If for example the terms and conditions for the repayment scheme is unreasonable, with for instance high interest rates, rather than strengthening their resilience the farmers could end up in a downward spiral of insolvency.

*Farmer organisations*

Having looked at dynamics around insurance and credit, it can be concluded that being part of farmer organisations, like the irrigation schemes, has given the farmers from the eastern villages access to information that the farmers from the western villages do not have. In the eastern villages the farmers themselves also pointed out other benefits from the membership, including how it brings them together to sort problems, like fixing fences and canals. Farmers said that being in the scheme they are able to approach Government/Department of Agriculture for help together, as a group. Farmers also mentioned the value of being able to ask advice from other farmers, and of being able to discuss together how they can improve their farming practices. Only three farmers said that being part of a scheme does not really help them. It therefore seems like the farmers from the eastern villages themselves generally feel that being part of an irrigation scheme provides them with some form of help and security.

Overall, membership in irrigation schemes can be seen as a solid indicator of resilience for the farmers in Bushbuckridge, making the farmers from the eastern villages less vulnerable than the farmers from the western villages.

*Context and inter-linkages*

While the vulnerability indicators gave some insight into the vulnerability of the farmers, they did not necessarily give the full picture, as was reflected when contextualising the sensitivity and resilience indicators. For example, the indicators missed to uncover the many challenges faced when dealing with the irrigation systems in the eastern villages, challenges that potentially reduce the degree to which irrigation strengthens resilience. What is more, looking into some of the indicators in more detail allowed for an understanding of the fact that while heavy rainfall events are more frequent than droughts, droughts cause more extensive losses. It also illustrated how farmers from the eastern villages, through the interaction at the irrigation schemes, have more access to information on insurance and credit than the farmers from the western villages, thus confirming the positive role of farmer organisations. What is more, the analysis outlined some of the reasons why the farmers are not accessing insurance and credit. These are all important factors when assessing how farmers can better deal with current challenges, and when considering how to overcome barriers to adaptation.

Lastly, using the approach of the Turner el al. (2003a) framework, which is to emphasise the coupled character of mechanisms and processes, revealed important system linkages. To illustrate, the indicators that were used for the exposure component of the vulnerability analysis showed how farmers experience a lot of variability in the timing of the onset of the summer rainfall and the mean monthly and annual rainfall, and little variability in mean monthly temperatures. What is more, they showed that farmers are only half as exposed to droughts as they are to heavy rainfall events. This should be linked to the findings related to the type of events that seem to be causing the most crop damage amongst the farmers. It was found that heavy rainfall events are most common, while drought, though less common, tends to cause greater impact.[57] This corresponds well with the exposure component discovered in the vulnerability indicators, which identified heavy rainfall as more common than drought. What the indicator failed to highlight though is the fact that even though droughts are less common, they seem to make a greater impact than the heavy rainfall events. This is important information when trying to understand the vulnerability of small-scale farmers to extreme weather events and climate variability. For example, if considering the implementation of adaptation measures in the area, a look at the number of heavy rainfall events detected compared to the number of droughts could lead focus towards heavy rainfall events only. An inclusion of the impacts would show how a focus on drought

[57] According to the farmers' own experience.

could be just as, if not more, important, and thus lead to a different approach to adaptation.[58]

In the end the vulnerability analysis of farmers in the Bushbuckridge area has highlighted similarities and differences between farmers from the eastern and the western villages. By taking non-climatic stressors into consideration this analysis has also shown how important it is that policies should not be designed to address climatic variability and change single-handedly, but should rather take a spectrum of stressors into account. The comparison of the two areas, which are a mere 40 minutes drive apart, also shows the need for community specific responses, as a one size fits all approach will not work in the differential settings illustrated in the western and the eastern villages. Lastly, the analysis also illustrated the importance of analysing inter-linkages between indicators and of going beyond the quantitative aspects of the different indicators.

## 6.3 Coping and adapting –a current lack of capacity

Although coping and adaptation measures are evident within the communities, the capacity to adapt more systematically was limited. As was outlined in the conceptual framework, coping tends to be seen as the short-term capacity or ability to survive (Smit and Wandel, 2006), and can thus be seen as less desirable than more long term, sustainable ways of responding to stress. According to Casale et al. (2009) people get caught in a trap of coping when they are unable to override or reduce the relevance of certain shocks. It thus seems that the farmers in Bushbuckridge have to resort to mechanisms that enable them to get by every year, rather than finding long term sustainable ways that will allow them to override the stress.

In this research three climatic stressors surfaced as the most common triggers for coping and adaptation mechanisms, namely late onset of the summer rainfall, heavy rainfall and high temperatures. Table 6.1 below outlines the key impacts and responses to these stressors.

[58] Importantly though, a more comprehensive and statistically relevant survey, as well as a more robust methodology for detecting droughts would be necessary if this research was to directly inform adaptation activity in the Bushbuckridge area. This research should rather be used as a guideline for further research.

| Climatic stressor | Impacts | Coping and adaptation mechanisms |
| --- | --- | --- |
| **Late onset** | Irrigation water not enough<br>Water scarcity as rivers/dams run dry → friction among the farmers<br>Increasing uncertainty over planting/preparation dates<br>Too dry to plough/plant – sometimes have to delay<br>The crops don't grown well and seeds die | Delay ploughing/planting/farming<br>Delay ploughing/planting/farming in homestead but not in wetland<br>Fetch water in river<br>Plant smaller area<br>Plant more if rain comes<br>Plant cassava and maize<br>Avoid planting specific crops<br>Irrigate |
| **Heavy rainfall** | Crops become degraded or erode<br>Crops die<br>Maize grows tall, but does not bear fruit<br>Farmers can't go to the field, and so crops and weed grow uncontrolled | Add soil after erosion<br>Do mulching<br>Not cut down natural vegetation/grow vetiver grass<br>Build furrow<br>Grow vegetation in the furrows<br>Make bendy, not straight, furrows<br>Plough shallow<br>Locate the field away from the water way<br>Raise the beds<br>Build a tank<br>Plant early, making the crops strong before the heavy rain |
| **High temperatures** | Shortage of water<br>Soil quickly dries after irrigating<br>Crops burn in the sun (especially tomato)<br>Plants become weak or die<br>More insects that eat or destroy crops<br>More crop disease | Plant smaller area<br>Delay or shift planting season<br>Weed in the morning<br>Irrigate/irrigate in the morning and the evening/avoid irrigating in the day when the water is hot/irrigate more often<br>Leave grass between the tomato plants<br>Do mulching<br>Use sprays<br>**Nothing to do – can not afford buying nets/build greenhouse** |

**Table 6.1: Impacts and responses to the three main stressors.** Coping responses are in green, while adaptation responses are in red.

The most common climatic trigger for the coping and adaptation mechanisms is the delay of the onset of the summer rainfall.[59] In response to the delay in the timing of the onset, seven different coping mechanisms and one adaptation mechanism were discovered. Only one farmer mentioned the adaptation mechanism, irrigation, in response to delay in the timing of the onset. This can be related to the fact that while the farmers from the eastern villages have irrigation, the water is shared among the farmers in the irrigation schemes. This means that farmers follow watering schedules and cannot water freely when the absence of rain requires it. What is more, the irrigation systems are old and unreliable, making it an unreliable and inconsistent adaptation mechanism.

Heavy rainfall was found to be the second most common trigger for coping and adaptation mechanisms. As opposed to the responses to a late onset, the responses to heavy rainfall are dominated by long-term adaptation mechanisms. The large majority of the adaptation mechanisms were mentioned by farmers from the western villages; more specifically, by farmers in Motlamogatsane. This can be related to the work of AWARD, an NGO that worked with farmers from the village in the period 2004 to 2009. In this period AWARD had four participatory projects in Motlamogatsane, two of which focused on managing erosion due to heavy rains. The role of AWARD will be discussed in further detail in the section on the role of information and training. So while the farmers in Motlamogatsane are equipped with a number of adaptation mechanisms for dealing with heavy rainfall, the responses of the farmers from Phelandaba and from the eastern villages seem somewhat more limited.

For the last climatic stressor, high temperatures, four adaptation and three coping strategies were outlined by the farmers interviewed. More importantly though, many farmers also said that there is nothing they could do because they cannot afford options like buying nets. Shading and sheltering has been recognized as an important mechanism for dealing with changes in temperatures across Africa (Maddison, 2006), but due to the lack of financial capacity it was

[59] Note that the delay could also be related to the variability in the timing of the onset, which was highlighted in the analysis of historical data, making it difficult to predict when the summer rainfall will start.

seen as an inaccessible option among the farmers in Bushbuckridge.[60] While the three coping mechanisms, planting a smaller area, delaying or shifting the planting season and weeding in the morning, do not require any costs,[61] this is not the case with all the adaptation mechanisms. Sprays, unless one can *make* them themselves,[62] have costs related, and so are not always options for farmers. Changes in the frequency and timing of irrigation are also limited options for those with irrigation, as was highlighted in relation to delays and variability in the timing of the onset. The farmers in the schemes share water and are supposed to stick to scheduled irrigation times. So while changing irrigation times and frequencies were mentioned as an adaptation mechanism when temperatures are high, it seemed to be a contested issue causing friction among farmers, and highlights problems faced when sharing a limited supply of water. Leaving grass between the tomato plants to protect them from the heat and the sun, a seemingly free adaptation strategy, was also found to have unexpected costs. As the farmer using this method explained, he has to apply a larger amount of fertilizer as the grass feeds on the fertilizer. So farmers are aware of, and to some extent using, a number of adaptation mechanisms to deal with high temperatures. At the same time, financial capacity, as well as the issues linked to sharing irrigation water, limits the degree to which they are able to apply these adaptation mechanisms.

As for when the disasters strike and farmers lose crops and income, due to either climatic or non-climatic stress, coping options were found to include money from pensions, children's grants or off-farm employment, receiving help from other farmers or seeds from MABEDI, or planting a smaller area the next season. A recent study of communities in the Amajuba District, Newcastle (South Africa) and an urban market in Durban (South Africa) showed that pensions and grants

[60] Note that discussions in Bushbuckridge did not go into more affordable options such as using trees etc for shading.
[61] At least to some extent. Delaying or shifting the planting season could pose additional challenges, like availability of seeds and tractors for ploughing.
[62] Even making it has costs, (unless there is sufficient knowledge of local and freely available herbs and plants). For example, when trying to help a farmer with information on how to make homemade pesticides the researcher was faced with the problem where some ingredients were not accessible to the farmer, both because of affordability and accessibility.

are two of the main sources of income amongst the respondents (Casale et al., 2009). While providing something to fall back on, the use of children grants for farming and food in times of crisis raises the question of how this impacts the children's ability to go to school and to buy necessary material and uniforms. As was found in a study in Lesotho, some people indicated how they might take their children out of school in drought years, using the school fee money to feed the family (Ziervogel, 2004). While keeping the family alive this can have detrimental effects, as children without education are less likely to get out of the poverty trap.

While diversifying incomes with off-farm employment is a well recognized indicator of resilience (O'Brien et al., 2004b; Kasperson et al., 2005), Casale et al. (2009) pointed out how diversified activities mitigate stressors rather than overriding them and that it leaves people caught within a trap of coping. Looking at the other coping mechanisms that were outlined above, neither of them seem capable of leaving farmers better prepared for another season with crop losses, they are rather ways of getting by into the next planting season. What thus needs to be addressed is the question of how farmers can get beyond the point of just coping, just getting by. It can be argued that adaptation mechanisms that minimize the loss of crops to climatic stressors would potentially decrease the number of events where falling back on grants, help from other farmers and so on is required.

The investigation of the mechanisms that farmers are currently using to cope with and adapt to climatic stress has given an understanding not only of the different mechanisms, but also of the degree to which farmers have to resort to just coping rather than to more long-term and sustainable adaptation mechanisms. It has shown that in response to delay in the timing of the onset of the summer rainfall, the farmers mainly rely on short-term coping mechanisms. With regard to heavy rainfall a large number of adaptation mechanisms surfaced, most of which could be attributed to the work done by AWARD in Motlamogatsane. The investigation also found that adaptation to high temperatures are limited, both due to lack of financial capacity and due issues related to sharing of water. Lastly, it found that when disaster strikes and crop and income is lost, farmers resort to a number of coping mechanisms.

## 6.4 Thresholds –illustrating the inter-related nature of stressors and responses

This research explored thresholds, focusing on the threshold beyond which the current adaptation and coping mechanisms are no longer able to maintain farming objectives. Through interaction with the farmers it became clear that, due to the inter-related nature of stressors and responses, it is somewhat difficult to relate the disruption of farming activities and yields to one specific stressor. For example, farmers were found to respond to a late onset of the summer rainfall by delaying farming activities, but there were also cases where farming activities had been delayed because of a death in the family or because the queues for tractors for ploughing were too long. There were also examples where the interaction of two stressors create thresholds, as will be discussed further below.

In relation to a delay in the onset of summer rainfall, it could be found that there are signs that some of the crops, more specifically madumbis, peanuts and cowpeas, do not grow well if they are only planted at some point in December. If the onset is to shift towards December on a regular basis, the farmers might then have to shift the types of crops that they grow. Madumbis is one of the main crops grown in the western villages, and this could thus pose a serious challenge to the farmers there. When asked why they grow the crops they grow, the most common answer in the western villages was that they are used to planting these crops, and so they know how to grow them. What is more, the farmers also said that these are the crops that they are used to eating. Adaptation through the adoption of new types of crops could thus face challenges, both in that the farmers potentially do not know how to grow the new crops and in that they are not used to cooking with other types of crops.

For heavy rainfall it was found that one day of heavy rain can be enough to cause bad erosion and crop losses. More importantly though, it was argued that other factors like planting time, and thus the age of the crops, also plays a role in the degree to which the crops are damaged by heavy rainfall. This is further important if considering the main coping mechanism for dealing with late onset of summer rainfall, namely delaying planting times. The majority of rainfall in the region falls in December, January and February, and so if the farmers have to delay their planting until December the crops are young and more vulnerable to the heavy rainfall that takes place the following months. This thus reflects how it is necessary to consider the interaction of multiple stressors and responses in order to fully understand thresholds.

This is also the case in relation to temperatures. It was difficult to set any threshold with regard to temperatures, without also considering the availability of water, rainfall or irrigation. If it rains or the farmers are able to irrigate enough, then it seems that the crops are more likely to survive.[63] For example, farmers told of how crop losses in 2010 had been related to high temperatures combined with the late onset of the summer rainfall. This corresponds with arguments made by Slegers (2008), who finds that the distribution, as well as the amount of sunshine and rainfall should be in balance. Accordingly, farmers in Bushbuckridge argued that crops can manage relatively well at around 30 degrees Celsius, if they receive enough water. At temperatures of around 40 degrees Celsius, on the other hand, farmers argued that it becomes problematic, even when the crops are watered enough.[64]

The investigation of different thresholds thus illustrated some of the challenges that need to be addressed when analysing thresholds. Most importantly, the different climatic stressors cannot be analysed in solitude, as one can exacerbate or minimize the stress caused by another. The research also gave some indications of thresholds, for example there are signs that if the rainy season shifts towards later in the year farmers might have to look at changing the types of crops they grow. What is more, it was found that, one day of heavy rainfall can be enough to cause erosion, and that the timing of the events in relation to planting times is important. Finally, for temperatures is was indicated that 40

[63] Though it was unclear what could be considered as "enough".

[64] Here it should be noted that this is generalized across all the crops that the farmers are growing, and that more research is needed into the different types of crops. What is more, it is important to note that the farmers do not measure temperatures, and so these thresholds are based on perceptions rather than temperature records.

degrees Celsius might represent a threshold that makes it difficult to keep farming as usual, even when sufficient water is available.

## 6.5 Future projections of increasing temperatures and changes in rainfall patterns - additional adaptation required

This research has looked at what the climate change projections are indicating for the future, and how these will potentially create additional challenges for the farmers. For the future projections, the investigation went into the near (2046-2065) and distant (2081-2100) future, using one future scenario, A2.

For the rainy season, projections for the distant future period, 2081 to 2100, show the clearest trends. In the distant future there are indications of a wetting trend in the first half of the rainy season, September through November, and a drying trend in the middle of the rainy season, from December through March. This corresponds well with the slight indications that were found towards a very small increase in the number of heavy rainfall events, over 50 mm in one day, in the first half of the rainy season, more specifically in September and November, and a very small decrease of the number of events in the middle the rainy season, more specifically December and January.

Wetting and increase of the number of heavy rainfall events in the first half of the rainy season could on one side provide a good start for the season with sufficient moisture. On the other side though, an increase in the number of heavy rainfall events in the first half of the season could cause a lot of damage to young and vulnerable crops. For the middle of the rainy season, drying could lead to water scarcity and cause well grown crops to die. A decrease in the number of heavy rainfall events, on the other side, would mean that crops would be less prone to damage from erosion in the middle of the rainy season.

That being said, it is important to keep in mind that there is little agreement in the different models' outputs. So with regard to rainfall, what should be remembered for adaptation and agricultural management purposes is that there are indications of changes in the rainfall patterns. So farmers, extension officers and adaptation projects should thus prepare for what could possibly be new, or more inconsistent rainfall patterns. Rather than working with a deterministic view on the seasonal rainfall patterns, basing decisions on historical climate, there therefore needs to be a shift towards preparedness for working with a more stochastic climate.

For findings around temperature, on the other hand, there was generally good agreement between the model outputs, and these projections, while still used with caution, can be considered with some more confidence than the rainfall projections. For maximum temperature projections there were found to be quite consistent trends, with median increases of around two degrees through the year in the near future, and median increases of around four degrees in the distant future. These are quite significant increases, and could have detrimental impacts already by the middle of this century. As was argued by a MABEDI official, a two degrees increase would be very bad for the agricultural activities of the small-scale farmers in the area. The officer argued that a two degrees increase would

> *"really badly affect the farming in the area. Yeah, I don't think we could handle it. Because that requires enough skill and enough funding to be able to handle."*

As for changes in the inter-annual temperature variability it was found that May shows an indication of increase in variability. For the number of days with maximum temperatures of over 40 degrees Celsius there was found to be a trend towards a slight increase in the number of events through the year, but specifically so from September through December, the first half of the rainy season. This is also the planting season for the farmers, and could thus have detrimental effects, as the farmers indicated that they are currently unable to deal with temperatures of 40 degrees Celsius, even when there is sufficient water. The increase in days with temperatures of over 40 degrees Celsius is projected to peak in October. This is the month in which the summer rainfall, according to historical records,[65] most usually starts, and is thus an important month for farmers who plough and plant around the time when the rains start.

[65] Though, importantly, rainfall patterns can also change, and so it is possible that October will not be the most common month for the rain to start in the future.

While one should be careful with treating projections as deterministic, these projections give a picture of what the climatic future might look like for the farmers in Bushbuckridge. Importantly, cycles of climatic variations have not been accounted for, and so it cannot be said whether the projected changes are due to climatic change or due to cyclical climate variability. None the less, they indicate some quite drastic changes to status quo, specifically with regard to temperatures, and warn of conditions that could be detrimental for small-scale farmers, who are to some degree already vulnerable to climatic stress under the current conditions. This reflects the need for considerable focus on adaptation action in the Bushbuckridge area.

## 6.6 The role of information, training and support –challenged by limits to adaptation

This research has highlighted the importance of access to information and to relevant training and support, and illustrates some of the challenges faced in that regard. For example, the farmers from the eastern villages have much greater exposure to information than the farmers from the western villages, through the interaction that takes place in their irrigation schemes. It is thus clear that the irrigation schemes provide an environment that gives the farmers from the eastern villages better access to information than the farmers from the western villages. Several studies have found that access to information is important for shaping adaptation strategies (Challinor et al., 2007, Thomas et al., 2007, Speranza, 2010), and being part of irrigation schemes could thus potentially make the farmers from the eastern villages more likely to develop necessary adaptation strategies into the future.

While recognising the important role of access to information, it is important to bring out a finding from section 6.6, which showed how perceptions of credit and insurance can act as a barrier that must be overcome if farmers are to acquire credit and insurance. This highlights how access to information is not enough. There needs to be adequate information, and it needs to be communicated in a way that is relevant and comprehensible for farmers.

In the western villages farmers reported that they have not had any interaction with extension officers. On the other hand, farmers from the one western village, Motlamogatsane, have over a long period of time been working with an NGO called AWARD. As was previously mentioned, AWARD worked in Motlamogatsane in the period 2004 to 2009. One of the main focuses of AWARD was on managing erosion, and this is reflected in the many adaptation mechanisms that the farmers in Motlamogatsane outlined in relation to erosion. AWARD used a participatory process, and wanted to make the farmers come up with their own responses to the problem of erosion. While this research recognises the role of AWARD and the large number of adaptation mechanisms practiced by the farmers in Motlamogatsane to deal with erosion following heavy rainfall, it has not looked into the degree to which these mechanisms have reduced the impact and losses caused by erosion. Future research focusing on the role that these adaptations have played, investigating whether they have made the farmers less vulnerable to heavy rainfall events, is thus necessary.

AWARD's work with farmers in Motlamogatsane was not without challenges. As one of the research officers working in Motlamogatsane with AWARD pointed out, it has not been easy to make farmers change their ways. Also, out of the 100 people that came to the first project meeting, roughly 75 people followed through to the last meetings. This is a good reflection of how some farmers are not necessarily receptive to changing their ways, even though learning processes are in place to facilitate. A similar example was found in the eastern villages. An extension officer, talking about how he is trying to assist farmers in the irrigation schemes to farm independently,[66] said that the attitude and the mindset is a problem when trying to get them to adapt to new circumstances. Most of the farmers there are old, and they are finding it difficult to change, despite receiving information, training and guidance.

It can therefore be found that the introduction of new knowledge and methods can be challenged by a lack of willingness to change. That being said, it is also possible that extension officers working in the eastern villages, or staff working with AWARD, have been unaware of underlying reasons why some farmers find it difficult or show little interest in adapting new methods and strategies.

[66] This is in comparison to the old days when the irrigation schemes were managed by government and development corporations.

Another important point to mention is how the farmers in Motlamogatsane have stopped meeting and sharing information and knowledge after the end of the AWARD projects. Though the staff from AWARD encouraged the farmers to keep meeting and working together, the meeting activity ended not long after AWARD's projects were over. Lastly, in relation to AWARD's work, it should be mentioned that the farmers from the other western village, Phelandaba, some of whom farm in the same wetland as farmers from Motlamogatsane, had not even heard about the benefits of the most common adaptation method used in Motlamogatsane, leaving the natural vegetation in the wetland. This reflects what has been argued by Maddison (2006), that close geographical proximity does not necessarily mean that an exchange of information takes place[67].

The interaction with extension officers and staff from AWARD has thus highlighted some of the challenges faced when introducing new knowledge and information, and when trying to facilitate change. The challenges are related to what Adger et al. (2009a) refer to as endogenous limits to adaptation.[68] Adger et al. (2009a, p.349) argue that "adaptation to climate change is limited by the values, perceptions, processes and power structures within society." The challenges that have been outlined here, perceptions (of insurance and credit), resistance to change and the lack of will and capacity to continue a process without someone to drive it, can therefore be referred to as endogenous limits to adaptation. Such limits highlight the importance of ensuring that adaptation programs and interventions are sensitive to local culture and conditions.



[67] While recognizing this could be linked to a number of factors, including cultural and tribal differences, it is not within the scope of this research to go into the underlying reasons in any more details.
[68] Note that this is not the threshold related limits to adaptation.

# 7. Conclusion

This section brings together the concluding elements emerging from the findings. This includes emphasis on vulnerability theory, as well as on current thresholds and limits to adaptation that work to inform future adaptation processes.

## 7.1 Applying vulnerability theory in practice

The recognition of the complex environment in which farmers live and work is not new. Literature has widely embraced the relevance of multiple climatic and non-climatic factors in shaping vulnerabilities (Risbey et al., 1999; Smit and Skinner, 2002; O'Brien et al., 2004b; Meinke et al., 2006; Morton et al., 2007; Gbetibouo and Ringler, 2009), as well as the fact that vulnerability is further shaped by *interacting* biophysical and socio-economic factors (Cutter et al., 2000; Benhin, 2006; Casale et al., 2009; Speranza, 2010). The integrative framework developed by Turner and his colleagues (2003a) in the Research Assessment Systems for Sustainability Science Program elaborates on the inter-related, multi-stressor complexity of vulnerability through focus on the coupled nature of socio-ecological systems (SES). In using the approach of the Turner et al. (2003a) framework, the research in Bushbuckridge highlighted the relevance of non-climatic factors in shaping the vulnerability of farmers. This is important, as it reflects the need to create policies that are not aimed at addressing climatic variability and change single handedly, but rather takes a spectrum of stressors into account. One aspect that has not been considered in this research, but which plays an important role in the coupled SES, is natural resources, such as soils and forests. Future analysis should thus address SES beyond climatic and agricultural aspects, by including the role of natural resources.

With regard to the interacting nature of stressors and responses, the Turner et al. (2003a) framework highlights the need to investigate the coupled aspects, but provides little methodological guidance with regard to how this can be done. While the research in Bushbuckridge was able to highlight some of the inter-related aspects, in terms of how stressors interact to shape thresholds and how adaptation and coping responses can address more than one stressor, this was discovered more by coincidence than by intention. Therefore, while the Turner et al. (2003a) framework should be praised for its effort to incorporate the full complexity of SES, further work should focus on developing methodologies for how the inter-related nature of stressors and responses can be analysed within the framework.

Another important aspect that the research in Bushbuckridge confirmed is that the conditions that shape vulnerabilities can be community specific. This has been the argument in many previous studies (Smit and Wandel, 2006; Casale et al., 2009; Ziervogel et al., 2006a), and can now be further strengthened by the findings from Bushbuckridge. Location specific vulnerability and the location specific factors that shape vulnerability, reflect the need for community specific responses, as a one size fits all approach will not work in the differential settings illustrated in the western and the eastern villages. This supports the argument by Eriksen et al. (2005, p.303), that "no one model for decision-making and policy intervention can easily be applied across any community." It further suggests that while national policies should focus on a multi-stressor environment, they should at the same time allow for regionally and area specific approaches.

Lastly, as was highlighted in the conceptual framework, the applicability of the Turner et al. (2003a) framework is challenged by its complexity (Eakin and Luers, 2006). While the research in Bushbuckridge has incorporated a number of aspects from the framework, it has not been able to consider the full range of components, inter-linkages and feedbacks. It can be found that applying the full complexity of the framework is well beyond the capacity of small and medium research projects.

## 7.2 Coping and adapting –current thresholds likely to be more commonly exceeded in the future

The focal point of this research has been to analyse how farmers are coping and adapting today, in order to understand how they are likely to be able to deal with future change. The table below gives an overview of the three climatic stressors that have been the focus of this research, outlining thresholds and future projections in relation to current responses.

| | Late onset | Heavy rainfall | High temperatures |
|---|---|---|---|
| **Nature of stressor (historical records)** | High variability in the timing | Average of 18 heavy rainfall events (>100 mm/3 days) in the 35 year period 1960 - 1995 | Low inter-annual variability in mean monthly temperatures |
| **Response mechanisms** | Dominated by short term coping mechanisms | Dominated by long term adaptation mechanism (mainly due to response mechanisms used in the one village after cooperation with local NGO) | Dominated by long term adaptation mechanisms, all of which are not widely available to all the farmers |
| **Threshold** | Some point in December (only for some crops; madumbis, peanuts and cowpeas) | One day of heavy rainfall can be enough to cause erosion | It becomes difficult to keep crops healthy and alive at temperatures over 40 degrees Celsius |
| **Complicating factors** | Other factors than a late onset can trigger a delay in farming activities | The planting time and the age of the crop is important for the impact caused by heavy rainfall | Impact from temperatures depends on water availability |
| **Future projections** | Projections indicate wetting in the first half of the rainy season, but the little agreement among the GCM outputs | Projections indicate increase in number of heavy rainfall events (over 50 mm in one day), but there is little agreement among the GCM outputs | Projections indicate a temperature increase of around 2 degrees through the whole year by the middle of this century, and increase in the number of days with over 40 degrees Celsius in the first half of the rainy season. |

**Table 7.1: Outline of current climatic stressors and related responses, thresholds and future projections**



The research shows that, in the cases where farmers in Bushbuckridge are unable to avoid the loss of crops and income, they resort to a number of short-term coping mechanisms. These are mechanisms that enable them to get by until the next season, but which might require that they plant less the following season, or that childrens' schooling is affected as child grants have to be used for household and farming purposes. These mechanisms do not help farmers get beyond the point where they are just getting by. While highlighting the need for building the capacity of farmers beyond the point where they are just coping, this further brings out the need to minimize crop losses caused by climatic stress, and thereby reducing the number of events where farmers have to fall back on money from for example child grants.

When considering the responses to climatic stress, the research found that farmers mainly employ short-term coping mechanisms for dealing with delays and variability in the timing of the onset. Therefore, while the farmers get by from season to season, they have few mechanisms by which they can override, and permanently reduce their vulnerability to variability and delays in the timing of the onset. There is the constant threat of experiencing crop losses if the rains do come late or at unexpected times. This is of concern, especially given that the climate is projected to change into the future. While it has been difficult to detect specific trends in the rainfall projections, there are indications that September through November could get wetter. This could be positive for the farmers, as wetting in the start of the rainy season could mean that the onset of the summer rainfall would not shift to later in the year. It would also mean that farmers would experience a good start for the season, with sufficient moisture. If this becomes reality, focus should be on reaping the benefits of change, adapting to climate change by taking "advantage of new opportunities" (Adger et al., 2003, p.192).

While not ruling out the fact that rainfall changes at the start of the rainy season could be positive, the spread in the downscaled model outputs reflect little confidence in the projections. It is therefore sounder to focus on the fact that rainfall patterns could change in the future, and that the changes could be either positive or negative or potentially both.[69]

The second climatic stressor investigated was heavy rainfall. Farmers were found to have a number of adaptation mechanisms to respond to this, mainly due to the work of a local NGO, AWARD. These mechanisms that limit erosion, were mainly used in Motlamogatsane, the village where AWARD had been working, and were not found to have spread across to other villages. Based on these findings it therefore seems that some of the farmers, more specifically those

[69] While it is not the focus of this study, it is important to note that there is likely to be a difference between farmers' ability to reap the benefits of positive change

from Motlamogatsane, are more capable of dealing with erosion than are farmers from the other villages.

Rainfall projections indicate, with relatively low confidence, that the number of rainfall events with over 50 mm in one day could increase slightly in parts of the first half of the rainy season. If this was to happen, there should be concern, as this is the time of the season when crops are young and weak. As the farmers interviewed highlighted, young crops are more likely to erode than older crops when exposed to heavy rainfall.

While drought has not been a focus when investigating coping and adaptation mechanisms, it is important to note that rainfall projections also indicate drying in the middle of the rainy season. Still, projections indicate an increase in the mean annual rainfall. If in the future there is overall more rainfall, but at new times and intensities, new water storage possibilities, as well as increase in current water storage capacities, might be necessary.

Due to the low confidence found in the rainfall projections, there should be caution with regard to how rainfall related issues are addressed. Research, projects and other interventions focusing on promoting adaptive actions, should thus be cautious with introducing adaptation mechanisms concentrating on specific changes in the rainfall. Rather than for example focusing on heavy rainfall in the first part of the season specifically, there should be a focus on managing heavy rainfall and erosion through the whole rainy season. Generally speaking, this reflects the need to shift from a deterministic view on seasonal rainfall patterns, towards strengthening farmers' capacity to deal with more unpredictable rainfall patterns.

For dealing with high temperatures, farmers were found to have a number of adaptation mechanisms, some of which are not accessible to many of the farmers due to the related costs. Importantly, many of the farmers said that there is nothing they can do about high temperatures, as they cannot afford options such as nets, which is not to say that there are no affordable adaptation mechanisms. The work that AWARD did on erosion with the farmers from Motlamogatsane shows how affordable and accessible adaptation options can be discovered through a process of reflection and knowledge sharing within the community.

While the temperature projections have relatively high confidence, they should still be used with caution, due to the many uncertainties related to climate modelling and downscaling. Still, the direction of change, increasing temperatures, can be used as a guideline for future adaptation work. Given that small-scale farmers are limited in their current capacity to deal with high temperatures, there should be specific focus on accessible and affordable options through which farmers can protect their crops from the heat.

As has been outlined above, small-scale farmers in Bushbuckridge have somewhat limited capacity for dealing with current climatic stress. Climate change projections indicate that small-scale farmers in Bushbuckridge will experience changes in rainfall patterns and increasing temperatures. This further implies that the current thresholds of what the farmers are able to deal with are at the risk of being more commonly exceeded in the future, including the summer rainfall only starting in December, heavy rainfall around planting times and more frequent days with over 40 degrees Celsius. Projections, together with the fact that historical data from the area is also showing trends of temperature increases and drying. reflects the need for considerable focus on adaptation action in the Bushbuckridge area, and on strengthening the farmers' general capacity for dealing with climatic stress. Such focus would be necessary in order to shift the current thresholds to a point where they are not repeatedly exceeded in the future climate.



## 7.3 Addressing limits to adaptation – need to focus on initiatives that include local institutions

The findings section outlined endogenous limits to adaptation that were discovered through the research in Bushbuckridge, limits that emerge from within the community. These limits include perceptions (of insurance and credit), resistance to change and the lack of will and capacity to continue a process without someone to drive it.

Focus on the current coping and adaptation mechanisms has further highlighted an additional limit to adaptation, namely farmers' lack of financial capital. This relates to poverty, a limitation that is commonly quoted in literature (Maddison, 2006; Gbetibouo, 2009; Speranza, 2010). As was repeatedly found among the farmers from Bushbuckridge, lack of financial means limit their ability to adapt, preventing them from for example improving or acquiring irrigation systems, from buying nets to protect crops from high temperatures or from buying fencing to keep livestock out of their fields.

One way to address these financial limitations would be to look at broadening farmers' access to credit. As the discussion section has outlined, farmers do not all know about the possibilities around credit options, nor do they know whether they qualify for loans. What is more, farmers are not necessarily open to taking on credit. A lot of work thus needs to be done with regard to providing the necessary information and overcoming such perceptions, giving farmers confidence in financial institutions. It might also be necessary for governments to provide subsidised programmes with low interest loans, through which there is very little risk of small-scale farmers falling into debt traps.

Accessible adaptation options at no or little cost could be another approach for dealing with current and future stress under financial constraints. The projects run by AWARD in Motlamogatsane illustrate how it is possible to identify affordable and accessible adaptation mechanisms through a participatory community process. This work done by AWARD, as well as the work done by extension officers working in the eastern villages, has further worked to highlight a limit to adaptation, namely resistance to change. In the case of Motlamogatsane, characteristics within households and or within the community could be the reason why only a proportion of the farmers participated through the entire process with AWARD. An internal limit to adaptation was also uncovered in the eastern villages, where extension officers found that farmers receiving training and guidance are resisting change. One of the challenges with such endogenous limits to adaptation is that it can be difficult to discover and understand the underlying reasons. Projects and interventions focusing on developing locally appropriate adaptation options must therefore be as sensitive and as aware as possible to local conditions, including culture, ethics, power structures and perceptions of risks. For example, if changes in temperature and rainfall patterns require that farmers shift to new types of crops, there should be a focus on the acceptance of new crops within a village or community. While farmers might on the one hand need guidance with regard to cultivation of new crops, it is also important to look at how the new crops are perceived in their households, whether people can get used to cooking and eating them.

The last limit to adaptation, the lack of will and capacity to continue a process without someone to drive it, was also discovered through the work of AWARD. As was outlined in the findings, farmers in Motlamogatsane stopped meeting and sharing knowledge after the projects with AWARD were finished, though AWARD had encouraged them to keep meeting and sharing information and knowledge. This example illustrates how initiatives that are driven by external actors lack the local champions that might be required in order to keep initiatives going. This finding is supported by Osbahr et al. (2010), who argue that the role of agency, in terms of local innovators and entrepreneurs, is an important factor if initiatives are to be sustained at local levels.

The latter example from Motlamogatsane further illustrates a problem associated with projects that work within limited timeframes. In order to address this problem of discontinuity, one should focus on initiatives that also include permanent local institutions, more specifically the government's extension officers. Extension officers have been found to play an important role in supporting farmers (Speranza, 2010), and research has found that farmers who interact with extension officers are more likely to adapt to climate change (Maddison, 2006). Projects run by external actors, such as NGOs and academic institutions, should therefore prioritise partnerships with local stakeholders, such as extension officers. Including extension officers in a participatory community process, such as that organised by AWARD in Motlamogatsane, could provide continuity after the initial project has ended. Continuity is crucial, as adaptation is a continuous flow of activities, decisions, attitudes and actions (Adger et al., 2005), and should therefore be treated as a process rather than an end point.

As highlighted in the research from Bushbuckridge, vulnerabilities are location specific, and inclusion of extension officers with knowledge of the local situation can add further value to the process. Capacitating extension officers to run participatory processes that identify locally appropriate adaptation options is another possible approach. As highlighted by Speranza (2010), training extension officers in marginal areas could help lift communities out of the perpetual poverty circle.

## 7.4 Recommendations

Findings from the research from Bushbuckridge support the argument that farmers live and work in a multi-stressor environment, where vulnerability is location specific. The research reflects the need to strengthen small-scale farmers' capacity to deal with challenges in their current environment, while at the same time preparing for future climatic change. Future climate change projections indicate that current thresholds, points beyond which farming objectives, under current practices and adaptation mechanisms, are no longer maintained, are at risk of being more commonly exceeded in the future. Climate change projections should therefore be incorporated into agricultural development that encourages a long-term perspective while at the same time dealing with current problems.

When considering how small-scale farmers can best improve their current conditions, and further improve their ability to deal with climatic change, it is important to keep in mind that people are "active agents rather than passive victims of circumstances" (Eriksen et al, 2005, p.302). This research proposes that a participatory community process is necessary at the ground level, a process that builds on local capacity and knowledge, and which can identify locally appropriate and suitable adaptations. This should be a participatory process that is aware of and sensitive to local considerations of culture, ethics, knowledge and risk. Local actors, such as extension officers, who have a continuous presence in farming communities, should ideally run such initiatives. This does not mean that external knowledge from scientists and practitioners is not required. As was highlighted by Maddison (2006), some of the possible limits to adaptation include both the lack of knowledge about adaptations and the lack of weather and climatic information. It is also important to remember that climate change projections indicate future conditions and extremes that are potentially beyond what farmers have experienced in their lifetime, and a participatory community process may therefore require scientific and professional input.

Such efforts as those involved in creating the participatory community processes outlined above come with a number of challenges. Firstly, creating the time necessary might pose a challenge both to farmers and to extension officers. Farming is a time consuming occupation, and many rural households also face daily and immediate issues and tasks, such as acquiring water for domestic use. It might therefore be difficult for small-scale farmers to find, or to prioritise, the time necessary for such a process. As for extension officers, they would have to add the process to their current work tasks.

At policy level, focus and prioritising is required, as resources should be brought towards training extension officers and providing them with the necessary resources. Accordingly, projects in NGOs and academic institutions should focus on partnering and knowledge sharing with local extension officers. This might be challenging, both in relation to making the necessary financial resources and skills available, and in relation to partnerships, as the willingness of stakeholders such as scientists, NGO workers and government officials to cooperate might be limited.

As the research from Bushbuckridge has illustrated, more research is required in order to further uncover and understand the inter-related nature of stressors and responses in the small-scale farming sector. Research should also focus further attention on the thresholds that reflect the point beyond which current practices and adaptation strategies are no longer able to sustain farming objectives, thereby guiding the adaptation process towards the areas where further adaptation action is needed. The limited scope of the research from Bushbuckridge also reflects the need for similar, though larger, community scale research that can work to strengthen the findings from this research.

In conclusion this research has shown that using a vulnerability framework helps to uncover context and location specific dynamics. The research has highlighted the need to focus on the current challenges facing small-scale farmers, while also preparing for future change. It is clear that adaptation initiatives need to include partnerships that are based on understanding local context and needs, and that further ensure continuity through which adaptation can be treated as a process rather than an end point.

# 8. Appendix

## Appendix A: Field Questionnaire

**Date:**__________ **Form number:**_____

**Location** (Village, or closest village):________________________________________

**1.1 Farmer:**
1.11 Name________________________________________

1.12 Gender: Male Female
1.13 Age___________
1.14 Educational level Primary school completed
Secondary school (Matric) completed
Other ____________________
1.15 What year did you start farming?________________________

**1.2 People in household:**

| | Name | Gender (f/m) | Age | Relation to farmer | Educational level | Role on the farm |
|---|---|---|---|---|---|---|
| **1.** | | | | | | |
| **2.** | | | | | | |
| **3.** | | | | | | |
| **4.** | | | | | | |
| **5.** | | | | | | |
| **6** | | | | | | |
| **7.** | | | | | | |
| **8.** | | | | | | |

**1.3 Farm size, activity, yield and losses:**
1.31 Total field area (ha):___
1.32 Planted area (ha):_____
1.33 Unplanted area (ha):___
1.34 Irrigated (ha):________

1.35 Crops usually grown in Winter season:
Crop Area (Ha or levies) planted last season Yield last season Fertilizer type/amount

1.351 Are these the types of crops that you have always planted in winter?

1.36 Crops usually grown in Summer season:

Crop Area (Ha or levies) planted last season Yield last season Fertilizer type/amount

1.361 Are these the types of crops that you have always planted in summer?

1.37 Why do you plant the crops described above?

1.38 Where do you buy your fertilizer?

1.39 Can you remember any extreme weather events that impacted your crops?

Year Season Type of weather event Effects/damage Time taken to return to normal yields

1.40 Have you found any ways to deal with the extreme events above?

**1.5 Farming and climate**

1.51 What are the climatic factors that are most important for your farming?
*(tick the factors on list below)*

Start of summer rainfall
Amount of rainfall during the season
Rainfall intensity
Dryspell duration
Rainy season duration
Maximum temperature
Minimum temperature
Mean temperature
Other (specify)

1.512 Why are these factors most important?________________________________

1.52 How does the weather affect your farming decisions?____________________

1.53 Does the general weather vary from year to year? How?__________________



1.54 Do these variations in weather from year to year impact your farming activities? How?________________________________________

1.55 When does the rainy season start? Is this how it has always been?______

1.56 How long does the rainy season last? Is this how it has always been?____

1.57 Has the weather pattern somehow changed over the years you have been farming? No Yes

*If yes*
1.571 How has it changed?______________________________
______________________________
______________________________
______________________________

1.572 How have you detected the change (measurements)?__________
______________________________
______________________________
______

1.573 How has this affected your farming practices?______________
______________________________
______________________________

1.58 Do you make use of seasonal climate forecasting? No Yes
*If yes*
1.581 Where do you access the climate forecast?________________
______________________________
*If no*
1.582 Why not?______________________________
______________________________

**1.6 Challenges and changes in farm management**
1.61 Have you changed practices/strategies on the farm since you started farming years? If yes, how, and what were these changes a response to? (drought, high prices of fertilisers etc)

| Year | Change | As a response to... |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

1.62 Have there been times where you've wanted to change your farming practices, but have been unable to? No Yes

*If yes*

1.621 What were the changes you wanted to make?________________

________________________________________________

________________________________________________

________________________________________________

________________________________________________

1.622 Why did you not make the changes?________________

________________________________________________

________________________________________________

________________________________________________

1.63 What do you find are the main problems you face as a farmer? Why?

________________________________________________

________________________________________________

________________________________________________

________________________________________________

________________________________________________

1.64 Have you got ideas for how you could better deal with these problems?__

________________________________________________

________________________________________________

________________________________________________

________________________________________________

**1.7 Health**

1.71 Are you or anyone in your household often sick?________________

________________________________________________

________________________________________________

________________________________________________

1.72 How often are any of your family members sick, so that farm working days or income from other employment is lost?

_______days/year

1.73 How much do you spend on healthcare every month? (including medicine, clinic visit, transport to clinic and traditional doctors)________________

________________________________________________

________________________________________________

**1.8 Infrastructure**

1.81 Does your household have electricity? No Yes

1.811 Which are your main energy sources?

Electricity Used for________________________________

Wood Used for________________________________

Paraffin Used for________________________________

Gas Used for____________________________________________

1.82 Does your household have a radio and TV? No Yes

*If yes*

1.821 Do you get any information about farming or weather from the tv or the radio?

________________________________________________________________

1.83 How many people in your household have a mobile phone?____________

______________________________________________________________________

1.84 Does the household have clean running water? No Yes

*If no*

1.841 Where do you access water?_________________________________

________________________________________________________________

1.85 From where do you get water for you farming activities?____________

______________________________________________________________________

______________________________________________________________________

1.86 Where do you sell your crops?

Town Type/Cost of transportation

___________________________________________________

___________________________________________________

___________________________________________________

___________________________________________________

___________________________________________________

1.87 How far is the distance (km) from where you farm to where you live?___

1.88 What are the travelling costs (R) from where you live to where you farm?

____________

**1.9 Finance**

1.91 Is the farmed land

Fully owned by farmer

Partly owned by farmer Ha owned_______ Ha rented__________

Rented by farmer Owner of the land____________

Other Specify_____________

1.92 Is the farm equipment (*tick, explain)*

Fully owned by farmer

Partly owned by farmer

Equipment owned_______________________________________________

Equipment rented/cost__________________________________________

Rented by farmer

Type/Owner of Equipment________________________________________

1.93 Does the farm have any form of insurance? No Yes

*If yes,*

1.931 With who have you got insurance?______________________

1.932 How did you hear about the insurance?__________________

1.933 How much do you pay for your insurance?_______________ Rand/month

*If no,*

1.934 Have you heard about insurance options available to you? No Yes

*If yes*

1.9341 Insurance from where?_______________________________

1.9342 How did you find out about the insurance?_____________

______________________________________________________________

1.9342 Why have you chosen not to get the insurance?_________

______________________________________________________________

______________________________________________________________

1.94 Does the household have any income other than from the farming? No Yes

*If yes*

| | | |
|---|---|---|
| Pension | ______________ | rand/month |
| Grants | ______________ | rand/month |
| Farming subsidies | ______________ | rand/month |
| Off-farm employment | ______________ | rand/month |
| Family business | ______________ | rand/month |
| Other | ______________ | rand/month |

Description____________________________________________________

______________________________________________________________

______________________________________________________________

1.95 Does the household receive any form of support from family/friends? No Yes

*If yes*

1.662 From who?__________________

1.661 What form of support (food, money, equipment etc)?___________

1.663 How often do you receive the support?_________________________

1.96 Do you, or anyone else in the household, have a loan? No Yes

*If yes*

1.961 What type of loan and from where?___________________________

______________________________________________________________

*If no*

1.962 Have you heard about any credit options available to you, and where have you received information about them?___________________

______________________________________________________________

1.963 If yes, why have you not accessed the available credit?__________
______________________________________________________________
______________________________________________________________

1.97 Are you, or is anyone else in the household, part of a savings group? (Describe)
______________________________________________________________
______________________________________________________________

1.98 Are you, or is anyone in your household, member of any farmer network/organisation?
No Yes
*If yes*
1.981 Which?__________________________________________

1.982 Does it cost anything?______________________________
1.983 What does the network/organisation do?______________
______________________________________________________________

## Appendix B: Focus Group outlines

**Focus Group Outline for Phelandaba:**

1. **Introduction** [5 min] I do a small introduction – say that I am here so that we can discuss what I found in the interviews, and so that they can share their experiences

2. **Icebreaker** [10 min] To get people talking by asking them to "Picture yourself in you homestead garden in 3 years time – what do you see?"

3. **The biggest problems** [20 min] Put out a bowl of water (representing lack of water – drought, having to depend on the rain) and animal toys (representing animals destroying the crops), and then ask them put their rock at the one they find is the biggest problem or in an independent pile if there are other problems that they think are bigger. Then start a discussion around why this or that is the biggest problem.

4. **Dealing with climatic stressors** [30 min]
We tell them "a story" centered around *the rain starting late*, then ask them what they would do. Try and engage everyone in the discussion.
When they have come with suggestions I add the ones that I found in the interviews (if they have not mentioned them)
Then ask who has been using those mechanisms and then ask if they have or why they have not been using them.
We then, if time, tell a story about how *heavy rain causes flooding* that erodes a large proportion of someone's crops, then ask them what they would do about it and how they would prevent the crops from being eroded. Try and engage everyone in the discussion.
When they have come with suggestions I add the ones that I found in the interviews (if they have not mentioned them).
While trying to find out how they try to decrease the impacts of floods, also try to find out how they actually deal with loosing a large proportion of their crops (how do they then get food on the table!).
5. **Threshold** [30 min] First focus on the most common response to late rainfall, delaying farming practices. Talk about scenarios of change –
It is the last week of September and it has not yet rained – can you wait until 1st week of October before you plow and plant?
It is the first week of October and it has not yet rained - can you wait until 2nd week of October before you plow and plant?
It is the second week of October and it has not yet rained - can you wait until 3rd week of October before you plow and plant?
It is the third week of October and it has not yet rained - can you wait until 4th week of October before you plow and plant?
It is the fourth week of October and it has not yet rained - can you wait until the first week of November before you plow and plant?
Trying to find out how long they can delay plowing or planting (keep in mind it might be different for different crops)
6. **Seasonal forecasting** [15 min]
Remind them of what a seasonal forecast is.

Some of them have said that they've heard seasonal forecasts on tv and radio – can they remember which programs (what time, what channel)

- Why do they not use the forecast they hear on tv/radio?
- What would make them use the forecasts?
- What type of seasonal climate information would they like, what would be useful for them and how would they use it?
- What would they do if the forecast was wrong? (for example not use it again)

7. **Return to that future vision** [10 min] Ask them to go back to the vision they created at the start, what are the barriers to making that happen? How can they help themselves make that happen?

**Focus Group Outline for Motlamogatsane:**

1. **Introduction** [5 min] I do a small introduction – say that I am here so that we can discuss what I found in the interviews, and so that they can share their experiences.

2. **Icebreaker** [10 min] To get people talking by asking them to "Picture yourself in you homestead garden in 3 years time – what do you see?"

3. **The biggest problems** [20 min] Put out a bowl of water (representing lack of water – drought, having to depend on the rain) and animal toys (representing animals destroying the crops), and then ask them put their rock at the one they find is the biggest problem or in an independent pile if there are other problems that they think are bigger. Then start a discussion around why this or that is the biggest problem.

4. **Dealing with climatic stressors** [30 min]
   We tell a story about how *heavy rain causes flooding* that erodes a large proportion of someone's crops, then ask them what they would do about it and how they would prevent the crops from being eroded. Try and engage everyone in the discussion.
   When they have come with suggestions I add the ones that I found in the interviews (if they have not mentioned them).
   While trying to find out how they try to decrease the impacts of floods, also try to find out how they actually deal with loosing a large proportion of their crops (how do they then get food on the table!).
   We then, if there is time, tell them "a story" centered around *the rain starting late*, then ask them what they would do. Try and engage everyone in the discussion.
   When they have come with suggestions I add the ones that I found in the interviews (if they have not mentioned them)
   Then ask who has been using those mechanisms and then ask if they have or why they have not been using them.
5. **Threshold** [30 min] First focus on leaving natural vegetation as a response to heavy rainfall and floods. How effective is it?!
   Can ask:
   For those who have started leaving vegetation – Do crops still erode when rain/flooding? Has there been any rainfall/flooding that the vegetation has not been able to buffer? If yes, can you remember how long it rained/how big the flood was? Has this happened more than once?
   How long must it rain/how high must the water be before the vegetation can not buffer the water
   Secondly, if time, focus on the most common response to late rainfall, delaying farming practices. Talk about scenarios of change –
   It is the last week of September and it has not yet rained – can you wait until 1st week of October before you plow and plant?
   It is the first week of October and it has not yet rained - can you wait until 2nd week of October before you plow and plant?
   It is the second week of October and it has not yet rained - can you wait until 3nd week of October before you plow and plant?

It is the third week of October and it has not yet rained - can you wait until 4th week of October before you plow and plant?
It is the fourth week of October and it has not yet rained - can you wait until the first week of November before you plow and plant?

6. **Seasonal forecasting** [15 min]
Remind them of what a seasonal forecast is.
    - Some of them have said that they've heard seasonal forecasts on tv and radio – can they remember which programs (what time, what channel)
    - What type of seasonal climate information would they like, what would be useful for them and how would they use it?
    - What would they do if the forecast was wrong? (for example not use it again)

7. **Return to that future vision** [10 min] Ask them to go back to the vision they created at the start, what are the barriers to making that happen? How can they help themselves make that happen?

**Focus Group Outline for Dingleydale:**

1. **Introduction** [5 min] I do a small introduction – say that I am here so that we can discuss what I found in the interviews, and so that they can share their experiences.

2. **Icebreaker** [10 min] To get people talking by asking them to "Picture yourself in your field in 3 years time – what do you see?"

3. **The biggest problems** [20 min] Put a pile of coins (representing affordability), a little car (to represent travel distances), put out a Pick n'Pay shopping bag / representing market problems – crops not good enough for national market/need help with marketing/too many farmers so shops sell the crops at low price) and put out a mini tractor (representing tractor delays/long cues). Then ask them put their rock at the one they find is the biggest problem or in an independent pile if there are other problems that they think are bigger. Then start a discussion around why this or that is the biggest problem.

4. **Climatic stressors** [30 min] We tell a story about there being very *high or low temperatures* that make the crops weak, and ask them what they would do. Will try to encourage everyone to participate in the discussion.

   When they have come with suggestions I add the ones that I found in the interviews (if they have not mentioned them).
   Then, if time, we tell them "a story" centered around *the rain starting late*, then ask them what they would do. Will try to encourage everyone to participate in the discussion.
   When they have come with suggestions I add the ones that I found in the interviews (if they have not mentioned them).
5. **Threshold** [30 min] Focus on using chemicals as a response to high/low temperatures. How high/low temperatures can they buffer? Try to establish a threshold
6. 
   Then, if time, focus on the most common response to late rainfall, *delaying farming practices*. Talk about scenarios of change:
   It is the last week of September and it has not yet rained – can you wait until 1st week of October before you plow and plant?
   It is the first week of October and it has not yet rained - can you wait until 2nd week of October before you plow and plant?
   It is the second week of October and it has not yet rained - can you wait until 3nd week of October before you plow and plant?
   It is the third week of October and it has not yet rained - can you wait until 4th week of October before you plow and plant?
   It is the fourth week of October and it has not yet rained - can you wait until the first week of November before you plow and plant?
   Trying to find out how long they can delay plowing or planting (keep in mind it might be different for different crops)
7. **Seasonal forecasting** [15 min]
   Remind them of what a seasonal forecast is.

- Some of them have said that they've heard seasonal forecasts on tv and radio – can they remember which programs (what time, what channel)
- What type of seasonal climate information would they like, what would be useful for them and how would they use it?
- What would they do if the forecast was wrong? (for example not use it again)

8. **Return to that future vision** [10 min] Ask them to go back to the vision they created at the start, what are the barriers to making that happen? How can they help themselves make that happen?

**Focus Group Outline for New Forest:**

1. **Introduction** [5 min] I do a small introduction – say that I am here so that we can discuss what I found in the interviews, and so that they can share their experiences (say that I hope they can learn through sharing experiences).

2. **Icebreaker** [10 min] To get people talking by asking them to "Picture yourself in your field in 3 years time – what do you see?"

3. **The biggest problems** [20 min] Put out a bowl of water (representing water problems because of problems with the irrigation system), put out a Pick n'Pay shopping bag (representing markets problems – everyone has ripe tomatoes at the same time/everyone growing the same crops/first come first serve/market not big enough ) and insect toys (representing insects eating/destroying crops). Then ask them put their rock at the one they find is the biggest problem or in an independent pile if there are other problems that they think are bigger. Then start a discussion around why this or that is the biggest problem.

4. **Climatic stressors** [30 min] We tell them "a story" centered around *the rain starting late*, then ask them what they would do. Will try to encourage everyone to participate in the discussion.

   When they have come with suggestions I add the ones that I found in the interviews (if they have not mentioned them).
   Then, if time, tell a story about there being very *high or low temperatures* that make the crops weak, and ask them what they would do. Will try to encourage everyone to participate in the discussion.
   When they have come with suggestions I add the ones that I found in the interviews (if they have not mentioned them).
5. **Threshold** [30 min] First focus on the most common response to late rainfall, *delaying farming practices*. Talk about scenarios of change:
   It is the last week of September and it has not yet rained – can you wait until 1st week of October before you plow and plant?
   It is the first week of October and it has not yet rained - can you wait until 2nd week of October before you plow and plant?
   It is the second week of October and it has not yet rained - can you wait until 3nd week of October before you plow and plant?
   It is the third week of October and it has not yet rained - can you wait until 4th week of October before you plow and plant?
   It is the fourth week of October and it has not yet rained - can you wait until the first week of November before you plow and plant?
   Trying to find out how long they can delay plowing or planting (keep in mind it might be different for different crops)
   If time, focus on using chemicals/sprays as a response to high/low temperatures. How high/low temperatures can they buffer?
6. **Seasonal forecasting** [15 min]
   Remind them of what a seasonal forecast is.

- Some of them have said that they've heard seasonal forecasts on tv and radio – can they remember which programs (what time, what channel)
- What type of seasonal climate information would they like, what would be useful for them and how would they use it?
- What would they do if the forecast was wrong? (for example not use it again)

7. **Return to that future vision** [10 min] Ask them to go back to the vision they created at the start, what are the barriers to making that happen? How can they help themselves make that happen?

## Appendix C: Data missing from historical weather station data

| Name (station number) | Variables Available | Time series used in analysis | Data missing in time series |
|---|---|---|---|
| **New Forest (Bosbokrand)** (0595195_4) | Rainfall | 01.01.1960 – 29.02.1996 | None |
| **Pretoriuskop** (0556460_W) | Rainfall | 01.01.1960 – 30.04.2006 | July 1994,<br>All year 1987,<br>All year 1988,<br>Apr/Aug/Sept/Oct 1984,<br>July 1965 |
| | Temperature | 01.01.1960 – 31.12.1999 | Nov 1986,<br>Apr/Aug/Sept/Oct 1984,<br>from Jan 1974 to Aug1981,<br>June/Aug-Dec 1973,<br>Apr/Nov/Dec 1971,<br>Feb/May 1967,<br>Feb 1966,<br>Feb/Mars/July 1965,<br>Dec 1963 |
| **Skukuza** (0596179_W) | Rainfall | 01.01.1960 – 30.04.2006 | All of 1987, 1988,<br>Feb 1964 |
| | Temperature | 01.01.1960 – 31.12.1999 | Nov 1975,<br>Feb 1964 |

## Appendix D: Overview of General Circulation Models (GCMs) used for projections

| | |
|---|---|
| **Ccma_cgcm3_1** | Canadian Centre for Climate Modelling and Ananlysis, Canada |
| **MPI ECHAM 5** | Max Planck Institute for Meteorology, Germany |
| **CNRM CM3** | Meteo-France, Centre National de Recherches Meteorologiques, France |
| **MIUB ECHO G** | Meteorological Institute University of Bonn, Germany |
| **GFDL CM 2.0** | NOAA Geophysical Fluid Dynamics Laboratory, USA |
| **GFDL CM 2.1** | NOAA Geophysical Fluid Dynamics Laboratory, USA |
| **IPSL CM4** | L'Institut Pierre-Simon Laplace, France |
| **CSIRO mk3.5** | Csiro Atmospheric Research, Australia |
| **GISS model ER** | NASA Goddard Institute for Space Studies, USA |
| **MRI CGCM 3.2a** | Meteorological Research Institute (MRI), Japan |

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