INDIGENOUS KNOWLEDGE SYSTEMS AVAILABLE TO CONSERVE SOIL AND WATER AND THEIR EFFECTS ON PHYSICO-CHEMICAL PROPERTIES ON SELECTED SMALLHOLDER FARMS OF KWAZULU-NATAL

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BSc Agriculture in Soil Science (UKZN)

Submitted in fulfilment of the academic requirement for the degree of Masters of Science in Soil Science

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Pietermaritzburg

2017

DECLARATION

I, **Bonginkosi Samuel Vilakazi,** declare that;

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Professor P. Mafongoya (Co-Supervisor)

ABSTRACT

Most of rural South Africa is semi- arid, experiencing a variable climate with extreme events such as droughts, floods or thunderstorms. In spite of this, communal farmers develop indigenous strategies to cope with these extremes in order to sustain agricultural production. The aim of the study was to document indigenous strategies that smallholder farmers in Bergville and uMsinga, in KwaZulu Natal use to predict weather, conserve soil and water in an effort to improve crop yields. Data was gathered through a baseline survey, which was supplemented with laboratory analyses to evaluate the physio-chemical properties of soil under different conservation practices in both areas. The baseline survey was carried out in sixteen villages, (eight villages each from uMsinga and Bergville). Information was gathered through 5 key informant interviews, 8 focus group discussions and 200 household questionnaires in each area. Soil characterisation was also done in the same sixteen villages by sampling from six conservation techniques namely zero and minimum tillage, intercropping, contour ploughing, fallowing and ridge/furrow planting, which were compared with conventional tillage. Soil samples were collected at 0-20, 20-40 and 40- 60 cm depth, then analysed for total C, N, P, pH, bases, EC, organic C, exchangeable Al and particle size distribution using standard laboratory techniques. Aggregate stability and bulk density were determined at 0-20 cm depth only by collecting aggregates and soil cores respectively.

Results showed that Bergville and uMsinga farmers rely on crop and livestock farming, home industries, poultry farming, salaries and social grants for income. Farmers also believe that the climate has been changing over the years through temperature rises and more erratic rain. They use indigenous indicators such as wind and cloud patterns, animal and bird behaviour, shape of the moon and position of the sun to predict weather. To cope with extreme weather, farmers rely on rainmakers and traditional healers in drought years, open drainage pathways to drain excess water during floods, burn incense to quell thunderstorms and lightning, then use the aloe plant, ashes and cow dung to control pests and diseases. Farmers also use drought tolerant crops (sorghum / millet), varieties (yellow maize) to cope with dry spells; and practices such as intercropping and crop rotation to sustain soil productivity. To conserve soil and water, farmers use raised beds, mulching, early maturing crops, furrows & ridges, earth dams and animal manure in the gardens; while contour farming, zero tillage, fallowing, terraces and animal manure are used in the fields. Techniques such as zero tillage, terraces, furrow/ridge, raised bed and mulching were adopted from science. Whereas fallowing, contour ploughing, manure addition, earth dams and rainwater harvesting are IKS. In uMsinga most farmers still prefer their indigenous methods. Whereas in Bergville, farmers prefer scientific methods.

Zero, minimum and conventional tillage treatments improved soil properties (bases, P, OC and aggregate stability) at Bergville whereas at uMsinga intercropping, contour ploughing and furrow / ridge performed better. The clay fraction did not have much influence on the performance of the techniques. In uMsinga, silt had more impact since it enhanced soil pH, Ca and K availability. High soil pH enhanced availability of bases (Ca, Mg and Na) particularly at Bergville, but negatively correlated with Al. Soil moisture enhanced availability of Mg, Na, P and C: N at but had a negative correlation with K. Whereas in Bergville, soil moisture positively correlated with OC but was negatively correlated with Na. Correlation results showed that there was no relationship between the different particle size fractions and tillage techniques. As a result, the higher performing techniques do not have their performance influenced by textural fraction. It was recommended that farmers in Bergville adopt zero and minimum tillage since they improved soil properties in the field. In uMsinga, intercropping and contour ploughing would be better soil quality enhancers than conventional tillage in the field, while the furrow/ridge is of more benefit in the gardens.

Key Words: Indigenous knowledge systems, soil and water conservation, KwaZulu-Natal

ACKNOWLEDGEMENTS

I thank God the Almighty for wisdom and strength.

I would like to acknowledge NRF for their financial support through their scarce skill bursary and DST for providing funds for the research expenses. I would also to thank Dr R Zengeni for her guidance, patience, constantly believing in me, encouragement and for academic assistance throughout the duration of this project. To Prof Mafongoya I am grateful for assisting with research funds.

I would like to extend my gratitude to the following:

FSG, Philakahle, Sinozwelo and the communal farmers of Bergville and uMsinga for helping and sharing the information.

DV, Khulani, Bangani Dube, Mata and Dr Zengeni for helping in data collection.

Miss Ntwanano Malepfane, Hloni Ndlela, Sfiso Mthethwa, Lindo Myeni, Uncle John and Nozi Mbava for help in lab.

Dr Khathab, Sabelo Shezi, Kwazi Zuma, Vuyisa Hlathini, Mdletshe, Mdolomba, Bangani Dube and Moirah for assisting with statistics.

Professor P. Muchaonyerwa for always opening his door whenever I needed assistance, sometimes in late hours of the day and weekends, I really appreciate.

Joh Buthelezi and Tezi Nala for assistance with laboratory assistance.

All my friends, I would put you under one umbrella so that no-one would be left out, for always pushing me

My lovely family for always loving, supporting and taking care of me.

Ngibonga wonk' umusa wenkosi ngamaqhawe namabutho ayizinkanyezi empilwni yami!!

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CHAPTER 1

GENERAL INTRODUCTION

Human population growth exerts pressure on farmers to produce more food so as to meet food demand, which leads to desertification, eutrophication and soil erosion. Sub-Saharan Africa is one of the most vulnerable regions to climate variability (Ajani *et al.,* 2013). Indigenous people in Sub-Sahara Africa are particularly vulnerable because they face widespread discrimination and exclusion from land and natural resources on which they depend on, due to lack of land and property rights (Ajani *et al.,* 2013). According to FAO (2006), between 1990/1992 and 2001/2003, the number of undernourished people increased from 169 to 206 million in Sub-Saharan Africa. Cooper *et al.,* (2008) further elucidated that most sub-Saharan African countries have been facing an agricultural production crisis since the 1970s, which accelerated in the 1980s. Cooper *et al.,* (2008) concluded that the reason for this is because sub- Saharan African communities rely heavily on rain-fed agriculture or pastoralism for their livelihoods.

South Africa is deemed a food secure nation, producing enough food or having the capacity to import it when the need arise (FAO, 2008). However, though South Africa seems food secure at national level, household food security in rural areas is often a problem (du Toit & Neves, 2014). Rural farmers, who rely more on rain-fed agriculture and have little off-farm income, experience problems of highly erratic weather. There are limited options available in rural areas to make a decent living; with the only resource at their disposal being degraded land. Crop yields cannot be sustained simply by adding chemical inputs, a standard approach to increasing yields in the past (Rarieya and Fortun, 2010). According to Barrett *et al.,* (2002), sustaining crop yields require understanding of the roots of problems at regional if not global levels, and the integration of different kinds of knowledge, both local and scientific. Degradation of natural resources such as decline in soil fertility due to soil erosion has serious effects on crop production hence soil conservation methods are needed to sustain crop yields (Rarieya and Fortun, 2010). Rarieya and Fortun, (2010) further observed that an increased incidences of weeds, pests and diseases, thus necessitating increased application of pesticide and herbicides, which may lead to other unintended environmental impacts occurring both on the sprayed site, and offsite, especially water systems. Soil and water conservation initiatives must be undertaken, and farmers must be proactive in responding to increased climate variability. Communal farmers, who rely more on rain-fed agriculture, experience declining crop and livestock productivity due to climatic variability. New strategies of agricultural production, such as irrigation and cross breeding, should be implemented in rural areas by government, NGOs and researchers in collaboration with communal farmers. Communal farmers utilize indigenous strategies which are locally based and suitable for their particular environment to mitigate and adapt to climate variability, thereby enhancing soil and water conservation. The major hindrance in developing countries is that technology generation and adoption are too slow to counteract the adverse effect of climate change. The traditional reductionist approach to science has a tendency to force the adoption of scientific strategies rather than incorporating socially relevant solutions (Meinke *et al.,* 2006). This is the reason why intended users of climate information generally fail to embrace innovations from research. Most subsistence farmers rely on indigenous knowledge to predict the climatic and make informed decisions on their farm planning, (Yaro, 2013). However, this knowledge has received little attention from scientists. Policy makers rely more on science rather than indigenous knowledge in their decision making. Therefore, subsistence farmers are omitted in implementing climate variability mitigation and adaptation strategies. Nyong *et al.,* (2007); and Thomas *et al.,* (2007) suggested that local knowledge should not merely be acknowledged by policy makers but should form the foundation of agricultural policies in a bottom-up approach. Appropriate climate variability adaption strategies should be implemented after a problem has been identified. The implementation and out-scaling of indigenous knowledge by communal farmers has also been impeded by poor information dissemination strategies, reduced income and non-supportive governmental policies.

The study was conducted in two districts namely Bergville and uMsinga of KwaZulu Natal Province, South Africa. Both regions have a large proportion of communal farmers who rely on rain-fed agriculture. Again in both areas, residential and arable land is mostly owned by the King through Ingonyama Trust Board (manage tribal land for communities). There is very little private land ownership hence decision making and policies on demarcation of pastures, forestry, arable land and water use are regulated by the King. As a result, arable land is often scarce in these two areas, leading to continued encroachment of crop land into forests. According to Nyiraruhimbi (2012), communal farmers in uMsinga in particular are experiencing higher declines in agricultural production yearly due to limited water availability and poor soil fertility. Because of this, most commercial farmers and government projects in uMsinga are switching to livestock instead of crop farming. On the other hand, local farming communities have been practising indigenous conservation methods to sustain farm production. However, these are often not well documented. According to Reid and Vogel, (2006) many communal farmers in KwaZulu Natal were abandoning crop farming due to climate variability however in other areas communal farmers are still practising crop farming no matter climate conditions. According to Shackleton *et al.,* (2010) crop production and livestock were the significant agriculture activities practised in KZN. Low water supply is the most challenging factor in crop production (Sotshangaye and Moller, 2007). According to Sotshangaye and Moller, (2007) farmers are willing to adopt supplementary irrigation however they are limited by the cost. There is need to interface indigenous knowledge with science without compromising the other. Combining the two systems would improve adaptation and implementation of mitigation strategies since both parties would feel valued. The aim of the study is to document indigenous strategies that farming communities use to predict weather, conserve soil and water in an effort to improve crop yields. It is also vital to understand the underlying factors that guide these choices.

Specific Objectives

1. To understand the farm structure and management options of selected communal farms in Bergville and uMsinga.

2. To assess farmers' knowledge on the state of the climate and the available indigenous knowledge system they use to cope with climate uncertainties.

3. To assess effectiveness of indigenous strategies that communal farmers use to conserve soil and water in comparison with those offered by science.

4. To evaluate the effect of different soil and water conservation practices used by smallholder farmers on soil physico-chemical properties.

Key Research questions:

1. What is the state of agricultural productivity in rural KwaZulu-Natal, and what sort of farming activities are farmers engaged in?

2. What indigenous strategies do farmers use to conserve soil and water and what factors guide these choices?
3. Which indigenous indicators do farmers use to predict weather, and how effective are they?
4. How readily do farmers adopt conservation technologies offered by science and what guides their willingness to adopt them?
5. What is the effect of different the soil and water conservation practices used by smallholder farmers on soil physico-chemical properties?

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

Climate variability and related extremes such as droughts or storms have a direct impact on agricultural production. They result in poor crop yields, especially in developing countries where agriculture production is mostly rain-fed. According to Salinger *et al.,* (2005), technology generation and adoption in developing countries are too slow to counteract the adverse effects climate change. Therefore agriculture and forestry are the most vulnerable sectors to climatic fluctuations (Salinger *et al.,* 2005). Thurlow *et al.,* (2007) discovered that climate variability also undermines attempts to reduce poverty and food insecurity, since most rural small-scale farmers rely on rain-fed agricultural incomes. Strategies to cope with climatic variability have to be implemented through thorough consultations with researchers, agricultural extension workers and farmers. Food security and sustainable development have to be at the core of mitigation strategies. Sustainable development may be the most effective way to frame the mitigation question and bring new strategies of adapting to climate variability (Ajani *et al*., 2013).

Farmers in Southern Africa living under harsh climatic conditions e.g. floods, droughts and thunderstorms, face many uncertainties in their farming (Mapfumo *et al.,* 2013). The capacity of farming communities and institutions to respond to emerging climate trends is often constrained by lack of access to information and improved technologies, as well as poor support mechanisms to promote assimilation of new knowledge. A study by Gandure *et al.,* (2013), in rural Thaba Nchu, South Africa showed that farmers' perceptions of climate risk and their approaches to adaptation are influenced by socio-economic and political factors. Thus, where there is political unrest and poor economic development, adaptation would be limited.

In an attempt to reduce the effects of climate variability policy measures such as the National climate change response green paper, and models e.g. the Water Resource Model by Mgeni have been developed in South Africa. Most of these measures have however failed to address climate impacts because communal farmers are often not well-educated on them so there is a deep resistance to adopt. Policy makers have also largely ignored the available indigenous knowledge strategies used by farming communities, viewing them as mostly primitive or backward. Indigenous knowledge is local knowledge that has been transferred from generation to generation. According to Makwara, (2013) indigenous knowledge is the knowledge, skills and methods of doing things based on local materials developed through experimentation and practical experience overtime by the people of the place, and adapted to the local situation. It is knowledge systems developed by a community as opposed to scientific knowledge that is generally referred to as modern knowledge (Ajibade and Shokemi, 2003). Indigenous knowledge systems (IKS) are part of Africa's heritage, which dates back to the pre-colonial era when they were developed to address various survival challenges. They are home-grown solutions that have withstood the test of time (Mapira and Mazambara, 2013). Mapira and Mazambara (2013), allege that European settlers who colonized the continent in the late 19th century sought to destroy, denigrate or marginalize IKS and replace them with Western views and approaches, which were in line with their goals of imperialism. This review argues that although it is not wise to be totally reliant on IKS for sustained agricultural production, policy makers and researchers must make an effort to study and incorporate them in strategic planning. New policies and adoption strategies must align with indigenous peoples' beliefs for effective adoption of climate mitigation options. Scientific knowledge is vital in decision making; however IKS should also be included in adaptation strategies since farming communities are more familiar with it and it often suits their local environment. The aim of this review is to assess the IKS used in climate predictions, soil and water conservation for crop yield improvement by communal farmers, and see how it can be integrated with scientific adaptation approaches for climate variability.

2.2. State of the climate in rural areas of South and Southern Africa

Arid and semiarid regions account for about 30% of the total world area and are inhabited by 1.1 billion people, which is 20% of the total world population (Sivakumar *et al.*, 2005). Africa has most populations inhabiting the semi-arid regions, which are characterized by low and variable rainfall and consistently high temperatures during the growing season (Salinger *et al.,* 2004). In subtropical areas of Africa climate variability, uncertainty and events such as droughts are common (Washington *et al*., 2005). According to Buckland *et al.*, (2000), at least 60 % of sub-Saharan Africa is vulnerable to drought, while 30 % is considered highly vulnerable. Catchment based assessments have shown that the eastern region of South Africa will receive an increased precipitation while the areas close to the Atlantic Ocean will receive reduced precipitation Lumsden *et al.* (2009). East coast of South Africa for example has been experiencing floods influenced by cyclones especially Demoina of Januanary 1984 (Jury *et al*., 1993). On the other hand, droughts are common in South Africa's arid and semi-arid rangelands, causing severe ecological and economic consequences (Vetter, 2001). They trigger the occurrence of natural fires, reduce water availability and cause desertification. Vetter (2001) discovered that while droughts may be short-term, and are followed by recovery during subsequent years of higher rainfall, they can trigger substantial and irreversible ecological and socio-economic changes. Extreme droughts in the Limpopo basin are very common, and have been recorded for more than a century at intervals of 10-20 years (FAO, 2004). A study conducted in rural Khomele of Limpopo province, South Africa, by Thomas *et al.,* (2007) revealev that the area was arid with mean annual rainfall of 400–500 mm. The average annual maximum temperature in Khomele was 28 ^{0}C in 1996 but increased to 32 ^{0}C by 2008 (SAWS, 2015). Studies also revealed that rural Mantsie of North West province, was also a dry region with 500–600 mm mean annual rainfall, and regular droughts (Thomas *et al.,* 2007). This area also experiences wide seasonal and daily variations in temperature, with very hot summers (average daily maximum temperatures of 32 ^{0}C in January) and mild to cold winters (average daily minimum of 0.9 ^{0}C in July) (DACE, 2008). There is a high variance between minimum and maximum temperatures; daily maximums range from 17 to 31^{0}C in the summer (October to April) and 4 to 20 ^{0}C in the winter (May to September) (DACE, 2008). Mcitsheni village in KwaZulu Natal province experiences mean annual rainfall of 800–900 mm, average annual minimum temperature ranges of 3.7 ^{0}C to 12 ^{0}C, and annual maximum tempertures of 13.5 ^{0}C to 25.7 ^{0}C (Annual report, 2011/2012).

According to Thomas *et al.,* (2007), there has been increasing inter-annual rainfall variability in South Africa, with an increase in heavier rainfall events in the early season and a predominance of low volume rainfall events later in the season i.e. in February and March (Thomas *et al.,* 2007). Climate data show evidence of a growing length of the dry season, resulting in a later start to the wet season, i.e. in late October-early November (Todd and Washington, 1998). Unlike in the past when rain used to start late August (Thomas *et al.,* 2007). According to Todd and Washington, (1998) in South Africa within the wet season there has been a trend towards fewer rain days in November and December and an increase in the overall occurrence of dry spells, causing potentially damaging rainless spells within the growing season. In several rural provinces of South Africa, namely Limpopo, North West and KwaZulu Natal; droughts have been frequent in the last two decades (1982–3, 1987, 1990 and 1994 in particular), (Thomas *et al.,* 2007). According to Mason *et al.*, (1999) droughts, are linked to the failure of rains within the expected October–March period, while floods are usually associated with cyclones e.g. cyclone Eline, which occurred on year 2000, that brought flooding to parts of Limpopo Province.

South Africa has a warm climate, and much of the country experiences average annual temperatures of above 17°C (DEA, 2015). The southern and eastern escarpments are the regions with the lowest temperatures, due to the decrease in temperature with altitude (SAWS, 2015). The warmest areas are the coastal areas of KwaZulu-Natal, the Lowveld of KwaZulu-Natal and Mpumalanga, the Limpopo valley and the interior regions of the Northern Cape. According to DEA (2015) the oceans surrounding South Africa have a moderating influence on the temperatures along coastal areas. The largest increase in median temperature is projected to occur over the central interior of South Africa, exceeding a value of 4°C during autumn and winter (DEA, 2015). According to Blignaut *et al.*, (2009) temperatures in South Africa have increased by approximately 2% over the 10 years 1997–2006 compared to what they were during the period of 1970–1979, and some parts of the country are at least 6% drier. The Limpopo Environmental Outlook Report (2016) showed that during the last five decades, the mean average temperature in South Africa has increased by 1.5 times the observed global average of 0.65^0C.

2.2.1 Climate variability impact on smallholder farming communities

Climate variability increases crop failure through droughts, heavy precipitation events, flooding, soil and wind erosion (Ajani *et al.,* 2013). According to Masson *et al.,* (1999), heavy rainfall events also damage engineering structures such as dams, further affecting water resource management and human livelihood. The heightened reliance of communal farmers on well water, which is quite sensitive to seasonal rainfall variability, leads to unreliable access and insufficient supplies for the households during dry seasons (Grace *et al.,* 2013). It is anticipated that climate variability and change in sub-Saharan Africa will have overwhelming impacts on agriculture and land use, ecosystem and biodiversity, human settlements, diseases and health and water resources (Ajani *et al.,* 2013). The population in sub-Saharan Africa is predicted to increase to over one billion by 2025 (Inocencio *et al*., 2003). In order to meet its food security requirements, agricultural production would have to increase by 6% per annum (Inocencio *et al*., 2003). This increase would be hindered by climate change and variability especially in rural areas where farming is rain-fed. According to Huq *et al.,* (2004) the least developed countries have contributed least to the emission of greenhouse gases, but are the most vulnerable to the effects of climate change. This is due to their location in some of the most vulnerable regions of the world (Africa and Asia) and their low capacities to adapt to these changes. They lack the necessary institutional and financial capacity to cope with climate change impacts and to rebuild infrastructure damaged by disasters (Sokona and Denton, 2001).

In South Africa, the agricultural sector plays a significant role in the country's economy. Evidence suggests that climate change could lead to a fall of about 1.5% of the country's gross domestic product (GDP) by 2050 – which is equivalent to the total annual foreign direct investment in South Africa (Turpie and Visserv, 2013). Studies which have looked at the impacts of climate change on agriculture in rural South African have focused on rain-fed maize production (Turpie and Visser, 2013). The need to improve smallholder maize production in a sustainable manner is important to South Africa as maize is a staple food (Walker and Schulze, 2006). Walker and Schulze, (2006) observed that smallholder maize production is characterised by low yields, which are often significantly lower than the potential for the land. Communal farmers in Potshini, Bergville, obtained 3.5 t/ha of maize yield, but after practising monoculture for 49 years the grain yield decreased to 0.8 t/ha (Walker and Schulze, 2006). The reduction in maize yield was attributed to dry spells which retarded plant growth, especially grain filling. However Smith *et al*., (2004) discovered that the climate and soils in the Potshini have the potential to produce yields in excess of 4 t/ha when using inorganic fertiliser and good management. It is estimated that by 2100, northern and southern Africa will likely have agricultural losses in the range of 0.4–1.3% (Boko *et al*., 2007). Abraha and Savage, (2006) suggested that crop production levels in response to changing climate could be studied using crop simulation models. A number of climate projections for South Africa indicate a decrease in maize production showing that every 1% decrease in mean annual rainfall will likely lead to 1.1% decline in the maize production (Blignaut *et al*., 2009; Turpie *et al*., 2002).

Kruger and Shongwe (2004) showed strong positive temperature changes for South Africa which negatively impact agricultural production. Tlhompho (2014) showed that cattle, goat, horses and sheep in the village of Ganyesa, North West, were also vulnerable to an extensive range of nematode worm infections, most of which had their development stages influenced by higher temperatures ranging from 25-30 ^{0}C. Small scale farmers rely on their livestock as source of income and food therefore if these are killed, poverty would increase. In Free State province, there were reports of droughts in the late 1990s and late 2000s confirming local perceptions that there has been a shift in climate towards more variable conditions that are less favourable to production (Zuma- Netshukwi *et al.,* 2013). Furthermore, Zinn & Harper (2010) indicatde that higher temperatures caused heat stress in plants leading to sterility of pollen and thus reduced plant productivity. A study in Ganyesa village, North West province showed that climate variability induced vector borne diseases such as heartwater, gallsickness and redwater in livestock that were transmitted by ticks, files, etc. whose breeding is often heavily influenced by temperature changes (Tlhompho, 2014). The soil in this area was also greatly affected by higher evaporation rates (since the area was dry for most parts of the year) making it more vulnerable to wind erosion (Tlhompho, 2014).

2.3 Adaptation by communal farmers to climate variability

Farmers' vulnerability to climate abnormality is often caused by lack of resources and support systems, as some have no means to adapt immediately. In South Africa, communal farmers have over the years developed their own mitigation and adaptation strategies by changing cropping strategies and employing water conserving techniques, and these have been passed on through generations, (Water Research Commission, 2008; Yaro, 2013). Most of these adaptation strategies fit with the farmers'perceptions on climate change, and its impacts on their farm operations and other livelihoods. The strategies employed by communal farmers do not hinge on large financial investments, as scientific strategies often do (Muller, 2009). A good example is the practise of organic agriculture as an adaptation strategy to conserve soil moisture, (Muller, 2009). Organic agriculture utilises readily available crop residues, organic manure and local seed. In rural Gladstone, South Africa, Gandure *et al.,* (2013) discovered that the primary adaptation and mitigation strategies used by farmers included the use of water harvesting techniques such as in-field rain water harvesting; changes in crop planting dates, and changes to more water-use efficient crop cultivars. These practices were aimed at adapting to long-term changes in climate.

According to Smit and Skinner, (2002), diversifying farm production activities has the potential to reduce exposure to climate-related risks and increase the flexibility of farm production to changing climatic conditions. Altering crop and livestock varieties, including the substitution of plant types, cultivars and hybrids, and animal breeds designed for higher drought or heat tolerance, has the potential to increase farm efficiency in light of changing temperature and moisture stresses (Chiotti *et al.*, 1997). Rotating crops and livestock production, and shifting production away from marginal areas reduces soil erosion and improves moisture and nutrient retention (Smit and Skinner, 2002). Moreover, soil moisture and nutrient conservation can be improved through the use of alternate fallowing and minimum tillage practices (Chiotti et al., 1997). Changing land topography involves contouring and terracing, and the construction of diversions, reservoirs and recharge areas as adaptation options (Smit 1993). This reduces farm production vulnerability by decreasing runoff and erosion, improving moisture and nutrient retention, and improving water uptake (de Loë *et al.,* 1999). According to Smit and Skinner, (2002) changing the timing of operations involves production decisions, such as planting and harvesting, to synchronise with the changing duration of growing seasons. This involves scheduling of crop and livestock production activities such as grazing (Chiotti *et al.*, 1997), irrigation (de Loë *et al.*, 1999), harvesting, mulches, planting, seeding, and tillage (Smit, 1993). Changing the timing of these farm practices has the potential to maximize farm productivity during the growing season and to avoid heat stresses and moisture deficiencies.

2.3.1 Challenges faced by farming communities in adapting to climate variability

Communal farmers have limited finances to access veterinary services therefore livestock diseases spread killing most of their livestock (Ogalleh *et al.,* 2012). Unlike commercial farmers, communal farmers are not receiving assistance from government and NGOs on when to plant and which crops are suitable. Accessing credit for expansion also requires drafting of business proposals and collateral which most communal farmers do not possess. They have less support to control disease outbreak which make them suffer huge production losses. According to Yaro, (2013), communal farmers are in danger of being exploited by NGOs for their own interest which may not necessarily benefit the farmer. However Ogalleh *et al.,* (2012) argued the weakness of communal farmers was mostly increased by lack of water storage facilities for irrigation purposes, wide spread poverty and lack of inputs for farming, e.g. fertilizer. Furthermore lack of appropriate technologies or the use of obsolete equipment for farming, high illiteracy levels and limited knowledge of modern methods severely hinder communal agriculture (Yaro, 2013). Communal farmers, especially in South Africa, do not utilize herbicides, insecticides and artificial fertilizer (due to their exorbitant costs) to enhance production which lowers the quantity and quality of yields (Muller, 2009).

2.3.2 Opportunities for farming communities to adapt to climate variability

Communal farmers have vast local knowledge and experience in farming, which corresponds well with the climatic conditions and soil characteristics of that specific area (Gandure *et al.,* 2013). Mixed cropping and diversified farming into other ventures such as poultry and livestock rearing helps them increase farm production and become food secure in spite of unfavourable climatic conditions (Zuma-Netshukwi *et al.,* 2013). In Free State, South Africa, Gandure *et al.,* (2013) discovered one strategy used by communal farmers was having farms at different locations to avoid total loss in the event of a poor climate or unfavourable soil conditions. According to Gandure *et al.,* (2013), communal farmers could have both seasonal and annual crops due to potential for irrigation by utilising rivers and streams close by. In Ghana, Yaro (2013), discovered that farmers cultivated around rivers for easier access to water, though this was usually associated with higher susceptibility to soil erosion along the rivers. Domfeh (2007), also added that the success of African communal farming was also heavily reliant on prayers and ancestral worship for good climatic conditions.

2.4 Indigenous Knowledge Systems (IKS) used in agriculture production by farming communities in South and sub-Saharan Africa

Indigenous knowledge systems (IKS) refer to traditional, cultural, local knowledge unique to a given culture or society (Mapara, 2009). Govender *et al.,* (2013) argues that IKS is a body of knowledge produced and owned by local people in their specific communities and passed on from generation to generation, through practice and oral channels. They are knowledge forms that have failed to die despite the racial and colonial onslaught that they have suffered at the hands of Western imperialism and arrogance. IKS are forms of knowledge that have originated locally and naturally, and are linked to the communities that produce them (Altieri, 1995; Hammersmith, 2007). According to Mapara, (2009), indigenous knowledge systems manifest themselves through different dimensions such as agriculture, medicine, security, botany, zoology, craft skills and linguistics. In agriculture, IKS promotes sustainable methods of cultivation by implementing environmentally friendly farming techniques. South African academic institutions and the government have recognized the importance of IKS in the development of the country (Govender *et al.,* 2013). The role of traditional kings, chiefs and herbalists in the social, economic and political development of communities and the environment are recognized for their value in society.

In spite of good advantages associated with IKS, they are also clouded with number of challenges. For instance, apart from the health sector in which its contribution can easily be acknowledged, in agriculture, IKS has scarcely been appreciated. Though IK contributes significantly to the welfare of rural people of Limpopo Province, South Africa through farming, its contribution to agriculture still remains informal (Department of Agriculture, 2008). According to Department of Agriculture, (2008) limited tools and skills to encourage the local people to open up and provide IKS related information is a weakness to implementing IKS. Indigenous farming methods are complex, environmental friendly, sustainable, cost effective, culture specific, and play a crucial role in cultivation of indigenous crops among communal people (Notsi, 2013). The domination of modern, profit orientated farming methods tends to marginalize indigenous farming which is sustainable and environmentally friendly. A science-based approach to agricultural development is needed in order to increase crop and livestock production (Ejeta, 2011). However, equally important is to consider the traditional, ecological, economic, and socio-cultural knowledge of local farmers (Bishaw *et al.,* 2013). Commercial farming usually requires large hectares of land, thereby causing deforestation, carbon emissions, soil erosion, desertification and land degradation. A study by Notsi (2013), in two farming communities of Lesotho and South Africa, revealed that both communities depended on indigenous vegetables such as theepe (*Amaranthus*), tenane (*Wahlengergia androsacca*), rothwe (*Cleome cynandra*) and morogo-wa-Dinawa (*Vigna unguiculata*) for food security and nutrition. These farmers also used readily available animal manure and residue mulch as fertilizers in vegetable production which were cost-effective and environmentally friendly. Farming communities' practise fallowing and intercropping which conserve soil and water thereby preserving biodiversity. According to Duri and Mampara (2007), institutional prohibitions such as taboos were designed by indigenous communities to develop positive societal attitudes towards the environment. Examples of taboos involve restricting the cutting and use of certain types of vegetation (that are used for medicinal herbs) or sacred forests, as such a practice is believed to bring 'bad luck' to the user. Mapira and Mazambara (2013) discovered that among the Manyika people in Zimbabwe, it was taboo to cut a muchakata (*Parinari curatellifolia*) tree, as village rituals are conducted under this tree.

2.4.1 IKS holders

There are different perceptions given to indigenous knowledge holders ranging from belittling, discriminating to undermining their life style. Therefore various terminology has been used to define indigenous knowledge namely, people's science, ethno-science, local knowledge, village science and folk-ecology (Mapira and Mazambara, 2013). IK holders are culturally distinct ethnic groups with a different identity from the national society. They draw their existence from local resources and are politically not dominant (Melchias, 2001). IK holders mostly rely on agriculture for food, hence soil and water are integral to their survival. Indigenous groups can be particularly vulnerable to climate change hazards because they face widespread discrimination and exclusion from policy and decision making as a result of government failures to recognize the legitimacy of their land and territorial rights. They also face direct and indirect impacts of climate change on the ecosystems which form the traditional basis of their livelihoods thereby threatening their survival, (Ajani *et al.,* 2013). The inconsistencies surrounding the definition of indigenous peoples such as traditional healers and rainmakers also explains the diversity and difference of indigenous knowledge holders with and within regions.

2.4.2 Indigenous indicators used in climate and weather predictions

Indigenous indicators are tools used by indigenous and local communities for management and conservation of resources. According to the Convention on Biological Diversity (2013), IK indicators are monitoring approaches related to biodiversity, ecosystems, land, water and other resources, as well as human well-being. They have been adopted after many years of traditional experimenting and observing the behaviour of that particular tool. Indigenous indicators that are widely used include wind, cloud patterns, animal and bird behaviour, plants and solar system (Zuma-Netshikhwi *et al.,* 2013).

2.4.2.1 Plant indicators used to predict weather

Farmers in rural communities use plant phenology such as the sprouting of tree leaves, flowering, and plant growth size to predict rainfall onset and whether it will be a good or bad crop year. Zuma-Netshikhwi *et al.,* (2013), noted that grass and shrubs in the veld that have developed new leaves symbolize the beginning of the planting season. According to Elia *et al.,* (2014) in Tanzania when rain is about to start, a tree species such as the Bloodwood *(Brosimum rubescens),* locally known as Mninga, large-leaved Dalbergia (*Dalbergia boehmii),* locally known as Mnyinga, the Baobab (*Adansonia digitata),* locally known as Mbuyu and Acacia (*Acacia tortilis*), locally known as Mkunguu, produce leaves and flowers which farmers use as indicators for forecasting the upcoming rainy season. Flowers start producing a stronger scent when it is about to rain and leaves of deciduous trees turn upside down during unusual winds. The leaves grow in a way that keeps them right side up during regular prevalent winds. Certain trees, such as water berry (*Syzigium cordatum*), grow where the water table is near the surface, signalling to herders where to dig wells to water their cattle and where to grow high water demanding crops. When IK holders use plants to forecast weather, they do not base their predictions on genetic observations, but rather on phenotypic characteristics of trees near their farmlands which they have studied over time (Zuma-Netshukhwi *et al.,* 2013). One of the most prominent climatic indicators used by communal farmers in South Africa to identify the summer season is the Cape Aloe *(Aloe ferox)* which sprouts and decorates the hills with its orange flowers thus showing season of pending rains (Zuma-Netshukhwi *et al.,* 2013). However, Gandure *et al.,* (2013) discovered that Cape Aloe *(Aloe ferox)* in the South-Western Free State actually does not flower until September, due to colder conditions, whereas flowering in warmer areas of South Africa is known to occur between May and August. Aloe ferox is adaptable to many conditions and it means that such traditional forecasting/prediction will keep much of its validity also under conditions of a changing climate (Zuma-Netshukhwi *et al.,* 2013). Therefore showing that the use and reliability of indigenous indicators is determined by specific climatic conditions hence different areas use indicators differently but with relevance to their local conditions.

2.4.2.2 Animal and bird indigenous indicators used to predict to predict weather

Indigenous farmers use the appearance of the Cape sparrow (*Passer melanurus*) birds as an indication of good rains to come. This is of course a purely qualitative assessment by the farmers, based on many years of experience (Zuma-Netshukhwi *et al.,* 2013). It serves as a reminder that they should prepare for field activities. Flocks of sparrows are observed in the South-Western Free State during the growing season, as they feed on seeds and insects. A flock of sparrows flying around the sky, with scattered clouds, indicates pending rain. Zuma-Netshukhwi *et al.,* (2013) further observed that heavy migration of flocks of birds, merging into widespread formations, resembles and therefore forecasts heavy rains approaching in that particular area. In the Northern Free State, if a herd of cattle is noticed to be hesitant to go to the veld for grazing, it shows that the rains will be coming soon (Zuma-Netshukhwi *et al.,* (2013). Other farmers mentioned that cattle lie down when the rain is about to fall. Local traditional farmers in Tanzania consider the appearance of millipedes, green grasshoppers and butterflies in large numbers as a sign that rain is imminent; while the emergence of abundant green grasshoppers is a sign of a good harvest year (Elia *et al.,* 2014).

2.4.2.3 Wind and stone indicators used to predict to predict weather

Although wind indicators can be said to be indigenous, they often show some level of dynamism. Western science has also tapped into these and used wind direction to predict rainfall patterns (Enock, 2013). Dry winds usually indicate reduced rainfall and higher temperatures; while heavy winds indicate higher rainfall and low temperatures. According to Zuma-Netshukhwi *et al.,* (2013); farmers strongly believe in observing the wind direction to predict the onset of rainfall, with westerly winds being used to forecast upcoming rains. When farmers observe strong winds blowing from west to east in September to November, they consider it a sign of imminent heavy rainfall in the upcoming season (Elia *et al.,* 2014). However when the wind direction is from east to west in July, farmers consider it a bad omen, characterised by less rainfall in the upcoming season. In a research in Tanzania by Elia *et al.,* (2014), they found that elderly farmers still possess knowledge on special stones, brought by ancestral spirits, which were used in predicting weather. When the rain season was approaching, traditional healers took blood from a chicken and placed it on these special stones which are round in shape. The elders left the special stones for one night and collected them in the morning. If the stones were covered with a significant quantity of water, it signified immense rainfall, and if covered with less water, this meant low rainfall in the coming season.

2.4.2.4 Solar system, stars and cloud indicators

The appearance of dark clouds is a well-known indicator of heavy rainfall and low temperatures. According to Zuma- Netshukhwi *et al.,* (2013), the appearance of dark clouds is also related to scientific reasoning. In Southern Africa, when the sun is positioned in the southwest during the rainfall season, the villagers also see this as signifying imminent rain. In addition, when the sun is positioned in the northwest, it is a signal of the beginning of the summer season (Elia *et al.,* 2014). Zuma-Netshukhwi *et al.,* (2013) discovered that the techniques of using star patterns and movements to predict rainfall onset, days to expect rainfall and rainfall cessation were highly used by local traditional people in the Free State province, South Africa, however the farmers could not explain in detail on how this works. IK holders believe highly in this technique of star patterns and use it as a guide on how and when to start farming.

2.5 Soil and water management strategies in smallholder farming communities of SA and Southern Africa

Smallholder farmers in Africa have been using indigenous strategies to conserve soil and water for centuries. According to Sanginga & Woomer (2009) the production gains of millet and sorghum in Burkina Faso were enhanced through the combination of water harvesting techniques such as zai pits (small, shallow water catchments) and placements of manure, crop residue and composts into these pits (Figure 2.1). Zai is a term that farmers in northern Burkina Faso use to refer to small planting pits that are 20-30 cm in width, 10-20 cm deep and spaced 60-80 cm apart (Motis *et al.,* 2013). English terms used to describe zai pits include planting pockets, basins, micro pits and small water harvesting pits. Seeds are sown into the pits after filling them with one to three handfuls of organic material such as manure, compost, or dry plant biomass. Instead of being lost to runoff, rainfall water is trapped in the zai pits close to crop roots. Zai pits are especially relevant to areas receiving low annual rainfall of 300 - 800 mm (Roose *et al.*, 1993). Higher rainfall amounts could cause water-logging of the pits. Zai pits function as a strategy to preserve both water and soil.

Figure 2. 1: Millet growing in zai pits in Burkina Faso (Motis et al., 2013).

Other soil conservation methods used include half-moon furrows, stone bunds and tied ridges which conserve soil water and increase nutrient use efficiency. Stone bunds (Figure 2.2) are used on 60% to 80% of cultivated land in Burkina Faso (Sawadogo, 2011), often in combination with zai pits. Established across the contours of the land, the stone barriers slow down water runoff to improve water-catchment capacity of the zai pits. Rock bunds can be implemented with materials that are obtainable for most smallholder farmers.

Figure 2. 2: Zai pits in combination with stone bunds (Motis et al., 2013).

In a zai pit trial by Motis *et al.,* (2013) in South Africa, legume and sorghum plants were established in alternating rows of zai pits (Figure 2.3). The combined grain yield of cowpea and sorghum obtained from this trial was three-fold that of sorghum grown on its own. Crop rotation was also implemented in this system, i.e. the rows of zai pits planted to sorghum in season 1 were planted to legumes in season 2. This is an important consideration in areas where traditional fallow periods are no longer an option due to the higher food requirements of an ever-increasing human population. A row-rotation system also increases the space between legume and cereal crop plants, thereby decreasing competition for plant resources (e.g., light and soil moisture) in comparison to what would occur if both the legume and cereal were to be sown in the same zai pit. Moreover, row rotation helps conserve both soil and water hence increasing fertility. In all, the zai system allows farmers to concentrate both fertility and moisture close to crop roots thereby greatly enhancing crop productivity (Motis *et al*., 2013).

Figure 2. 3: An experiment in South Africa with sorghum and legume plants grown in alternating rows of zai pits (Motis et al., 2013)

In a series of studies conducted in drought-stricken Masvingo in Zimbabwe, the growth of drought tolerant crops e.g. sorghum and pearl millet as well as adoption of cultural water harvesting techniques helped reduce runoff and extend water availability thereby stabilising crop yields, (Mugabe, 2004). These cultures water harvesting techniques used in these studies included tied and contour ridges, no till, mulch ripping and infiltration pits (Mugabe, 2004). Contour ridges that drains water away from the fields were found not to be appropriate especially in semi-arid areas where drought is frequent. They can be improved by digging infiltration pits in the contour at intervals (Mugabe, 2004). According to Mugabe, (2004) this techniques improves soil moisture storage, prolongs the period of moisture availability and enhances crop growth. Li *et al.,* (2007) assert that the ridge-furrow system not only increases crop yields by improving water availability to plants within the furrows, but also preserves the soil from erosion. Figure 2.4 shows the ridge/furrow system that is used to conserve soil and water by communal farmers to increase crop yields. The combination of ridges and furrows with gravel mulching in the field may be one of the most effective methods for harvesting rainwater which have been utilised by farmers (Li *et al.*, 2007). In such a system, the ridges are intended to act as runoff areas for rainwater harvesting and the furrows as planting belts. One of the advantages of the ridge-furrow system is that rainwater falling on the ridges can be re-collected in the planting belts or furrows and thus increasing availability of soil moisture to plant roots (Li *et al.*, 2000). According to Li *et al.,* (2007) ridge-furrows particularly those with covered ridges (CR) can significantly enhance rainwater harvest and crop productivity. The ridge serves as a runoff surface for harvesting rainwater and the furrow as a planting belt with increased soil moisture generated from runoff from the ridges. Li *et al.,* (2007), discovered that the ridges covered with plastic film were effective in rainwater collection in the planting belts or furrows than the uncovered ridges, while the uncovered ridges were in turn better than the simple flat soil as reflected by the differences in crop yields. Furthermore, soil moisture of the covered ridge plots was higher than that of uncovered ridge plots, which in turn were higher than that of flat soil plots (Li *et al.,* 2007).

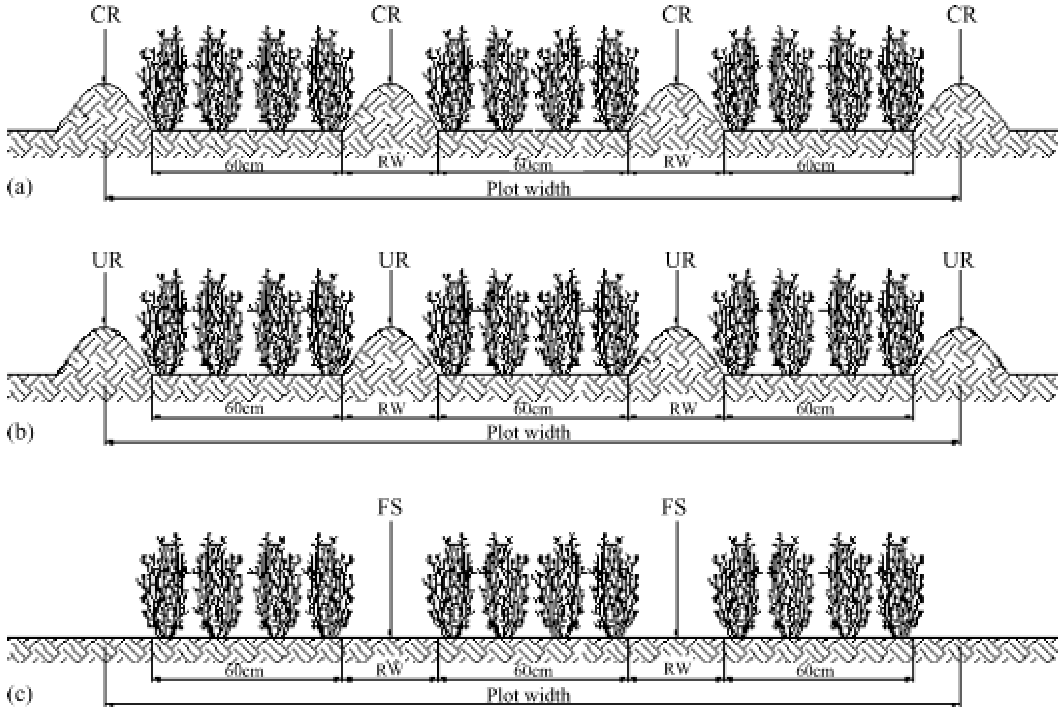

Figure 2.4: An illustration of the cross-sectional profiles of the field plots: (a) ridge-furrow system with film covered ridges (CR); (b) ridge-furrow system with uncovered ridges (UR); and (c) flat soil (FS) planting system with no ridge and no cover. Each plot consists of two complete and two half-ridges and two planting belts (or furrows). Ridge width (RW) or in the case of FS the bare soil between planting belts varies from 30, 45 to 60 cm, while the width of furrows or planting belts keep the same as 60 cm for all the plots (Li et al., 2007).

2.6 Integrating IKS with scientific knowledge

IKS is an essential element in the development process and the livelihoods of many local communities. However there is a pressing need to provide objective scientific information to assist the process of decision and policy making. It is not something that science alone can do, but it can facilitate the platform for IKS to be incorporated in adaptation and decision-making. According to Mapira and Mazambara, (2013) incorporating IK into climate variability concerns should not be done at the expense of modern/western scientific knowledge. Indigenous knowledge should complement rather than compete with scientific knowledge systems. How indigenous knowledge can best be integrated with scientific knowledge is one of the important questions facing indigenous communities, (Steiner, 2008). He further argues that modern science is more acceptable to the indigenous communities if it is integrated with what they already know. The Department of Science and Technology (DST) in South Africa managed to develop a national policy on IKS that promotes the interfacing of IK with other knowledge systems and therefore provide an opportunity for new products and services (Department of Agriculture (2008). According to Department of Agriculture (2008) small-scale rural farmers are encouraged to utilise kraal manure and plant residues instead of synthetic fertilizers. They are also advised to keep indigenous livestock such as Nguni cattle, which are more accustomed to the harsher local climate instead of imported breeds. Integrating IKS with scientific knowledge needs governmental cooperation which is often lacking. However the Department of Agriculture (2008) argues that South Africa and Uganda are a few of the African countries which have tried to mainstream IK into agriculture, environment and the health sectors.

2.7 Conclusion

Farming communities use plant, wind, stone, stars, clouds and animals related indicators in their traditional forecasting/predictions, mostly of immediate or seasonal rains and droughts. Agricultural decisions are made according to traditional knowledge and understanding of environmental conditions of their local area, obtained through years of experience. Farmers in semi-arid regions, especially in Southern Africa, experiences extreme conditions of higher temperatures and less or no rainfall and they usually use what is available to them to cope and adapt to the conditions. Several researchers revealed that most traditional farmers in the Southern Africa were not familiar with the application of external weather forecasts/climate predictions for agriculture and other science-based agro-meteorological tools where they exist.

They relied only on their own experience and traditional knowledge for farming and in decision-making. Unlike scientific findings some of the methods and strategies applied by the communal farmers, although they are time tested, are unreliable and not very precise. Scientific knowledge is easily obtained by commercial farmers who are able to read, surf on the internet and have satellite. Combining IKS and scientific knowledge would enable communal farmers to cope with climatic variability in semi-arid regions. Interfacing the two knowledge systems will improve accessibility to knowledge to both the young and old, illiterate and educated and people of all races. Farmers would be able to better predict the weather, thereby enabling them to choose appropriate farming methods and suitable plants for their region. Better methods of conserving water and soil might be developed through combining scientific with indigenous knowledge. The IKS is not documented hence out-scaling is difficult. More research is required on soil and water conservation under different tillage techniques in communal areas.

CHAPTER 3

FARMING SYSTEMS OF SELECTED COMMUNITIES IN KWAZULU NATAL, AND INDIGENOUS STRATEGIES TO PREDICT WEATHER IMPROVE CROP PRODUCTIVITY, MANAGE SOIL AND WATER

3.1 Introduction

Agriculture plays a pivotal role in supporting rural livelihoods and economic growth over most of Africa. In a study by Schlenker and Lobell, (2010), roughly 17% of GDP was derived from agriculture in Sub-Saharan Africa in 2005, with this fraction in excess of 50% in some countries. Schlenker and Lobell, (2010) observed that sub-Sahara Africa had the highest proportion of malnourished populations in the world, with one in three people being chronically hungry. Enhanced investment in agriculture by policy makers, researchers and NGOs is required if this sector is to meet its food security requirements. The impact of climate variability is mostly felt by smallholder farmers, predominantly in developing countries since they depend on natural resources for their livelihood, and are mostly located in semi-arid or arid regions. Poor socioeconomic status and non-supportive government policies tend to limit farmers' ability to adapt to climate change. Africa is one of the regions that is vulnerable to the impacts of climate variability and change (Challinor *et al.,* 2007). Its population is mostly distributed in rural areas and depends on rain-fed agriculture for food and income (Cooper *et al.,* 2008). Soils in most of rural Africa are often sandy and infertile. Recently, many regions of Africa have been experiencing a shift in rainfall and temperature patterns. According to Karmalkar *et al.,* (2012) mean annual temperature over South Africa has increased by around 0.6 ^{o}C between 1960 and 2006, at a rate of 0.14 ^{o}C per decade; while mean annual rainfall has decreased by 1.5 mm per decade since 1960.

In sub-Saharan Africa, climate variability, uncertainty and extreme weather events such as droughts, floods and cyclones are common (Washington *et al*., 2005). Since the population of Sub-Saharan Africa is concentrated in rural areas, most interventions should be directed to this sector to influence land and water management (Washington *et al*., 2005). Increased water shortage continuously reduces food quantity and quality of rural populations. Gbetibouo and Hassan, (2005), showed evidence that climate change would cause field crop losses in South Africa; with a 2 ^{o}C rise in temperature and 5% decrease in rainfall causing losses in net revenue of 2 to 16% in Eastern Cape, Gauteng, Mpumalanga and KwaZulu Natal. It is likely that lower rainfall and further increases in temperature in regions already hot can cause heat injury and water deficit for crop production. As a result, KwaZulu Natal and Mpumalanga crops, especially sugarcane production may be significantly lowered to the extent that farmers may be forced to switch to other more drought tolerant crops like sorghum (Gbetibouo and Hassan, 2005). Farming communities adapt to unfavourable climate by using local and easily accessible options such as changing planting dates, opting for early maturing cultivars, using drought resistant crops and cultivars. According to Abraha and Savage, (2006), early planting allows the crop to escape hot weather. Small-scale farmers have been utilizing indigenous knowledge system (IKS) to cope with climate extremes for a while. Indigenous knowledge refers to what indigenous people know and do for generations; having evolved through trial and error, and proven flexible enough to cope with change (Melchias, 2001). Despite the low publicity of IK, numerous studies show that it plays a critical role in agricultural development (Lwoga *et al*, 2010). Nyiraruhimbi (2012) in uMsinga, KwaZulu Natal discovered that IKS was used in planting, disease control and in removal of weeds, unhealthy plants and drying leaves, which are then used as organic sources of soil nutrients. Nyiraruhimbi (2012) observed that local farmers acquired knowledge for selecting seeds from their parents as they grew up, which was then shared among the villagers.

According to Eyong, (2007) IKS were developed through experimentation. Though these experiments were not documented, the knowledge systems were legitimised and fortified under suitable institutional frameworks, culture and practices. They have enabled indigenous people to survive, manage their natural resources and the ecosystems surrounding them. The problem with IKS is that it is marginalized, and the amalgamation of cultures has led to a situation where the knowledge of a specific group has become either diluted or absorbed (Seepe, 2001; Ngubane, 2006). The lack of validation and support from government and research has limited the advancement of IK (Hoppers, 2002). While western science has improved agricultural food production, it has several limitations. In some instances it has become a threat to sustainability of ecosystems; for example, the use of inorganic fertilizers has led pollution of soil and surrounding water bodies (Gowing *et al.,* 2004). Both IKS and western science have their own strength and weaknesses therefore integrating them would improve agriculture production. In KwaZulu Natal Province, South Africa, farming communities have been coping with climate extremes by using knowledge transferred from their forefathers. This knowledge is however very site-specific and ideal for short time periods. Knowledge documentation and sharing is also poor between different communal regions. There is need for out-scaling this information among different localities.

Communal farmers mostly make the decision about time of planting, types of crops to be planted, water conservation and livestock methods rearing after observing and predicting the weather using indigenous indicators. In a study done at Muroyi village in Zimbabwe, Makwara (2013) observed that indigenous weather forecasting complemented farmers' planning activities. Generally, the elderly predicted seasonal rainfall by observing natural patterns, while cultural and ritual specialists drew predictions from dreams or visions. Indigenous indicators have made significant contributions towards more sustainable development. A study in Zimbabwe observed that farmers' willingness to use seasonal climate forecasts increased when the forecasts were presented in conjunction with the indigenous climate forecasts (Boko *et al.,* (2007). Integrating indigenous and scientific knowledge would definitely help in conserving water and soil. The aim of the study was to understand the farming systems of selected farming communities in KZN, then document the indigenous strategies they use to manage soil and water, and make weather predictions to improve crop productivity.

Objectives

1. To identify indigenous meteorological indicators that farmers use to predict weather.
2. To review the management of the farming systems of selected communities.
3. To understand farmers' knowledge on the state of their climate and the available IKS they use to cope with climate uncertainties.
4. To assess efficiency of indigenous coping strategies that farmers use to maintain soil productivity in comparison with those offered by science.

3.2 Material and Methods

3.2.1 Site selection and description of study areas

Figure 3.1 depicts the location of the study sites. The study was conducted in two research areas, namely Bergville and uMsinga in KwaZulu-Natal Province of South Africa, with very distinct climatic conditions and soil types. Bergville is a relatively wet area receiving annual rainfall ranges of 750 to 1200 mm and temperatures of 19 to 26 °C (Nel, 2007); while uMsinga receives 598 to 740 mm of rainfall and has maximum temperatures reaching 35 °C (Phipson, 2012).

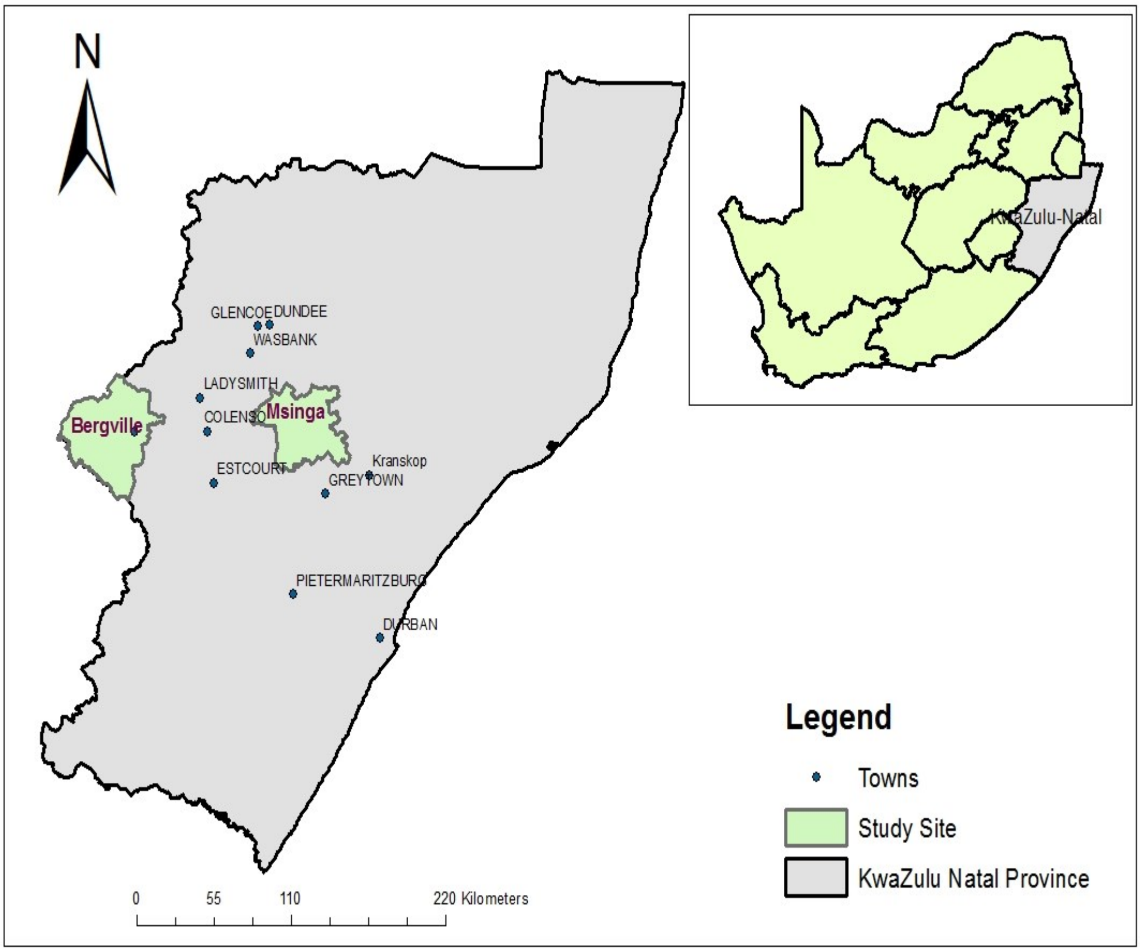

Figure 3. 1: Bergville and uMsinga research sites in KwaZulu-Natal Province.

Bergville is a town under Okhahlamba municipality and uThukela district, situated at 28° 43'59.88" South and 29° 22' 0.12" East, with an altitude of 1145 metres. It has a wide diversity of climate, topography, soils, vegetation and thus has good farming potential (Camp, 1999). According to Nel, (2007) Bergville receives 750 mm of rainfall per annum in the south east but up to 1 200 mm in the mountain foothills and adjoining areas in the west. Nel, (2007) discovered mean maximum air temperature of 25.7°C. The vegetation of Bergville is characterised by a diversity of tree and shrubs, ranging from dry thornveld and broadleaf bushveld in the riverine and broken terrain of the lower lying eastern portion of the district, through to lush montane forests and indigenous valley woodlots found along the Little Berg, and the lower slopes of the Drakensberg (Phipson, 2012). Phipson, (2012) explains that high rainfall along the Little Berg foothills gives rise to commercial forestry of *Pinus patula* and *Pinus eliottii*. Soils in Bergville are mostly plinthic with a high degree of arability, and slopes are moderate to gentle (Camp, 1999); making it a summer production area for arable annual crops (Phipson, 2012). The exceptions are winter wheat, irrigated pastures, cabbages and some horticultural crops. Both commercial and subsistence farming are practised in this region. According to Phipson (2012) commercial farming involves production of irrigated maize and soybeans (with maize yields of up to 10 tons per ha), while communal maize production levels, grown mainly on rain fed fields yield 2.0 to 2.5 tons per ha. Subsistence farming also involves cattle ranching and small scale production of dry bean and vegetables. Although there are opportunities for developing small scale commercial farming, a lack of expertise, skills and knowledge are constraints which must be addressed. Added to this are problems of over-grazing and stock theft which negatively impact farm productivity. Bergville soils are mostly Hutton, Pinedine, Clovely and Griffin soil forms which have good agricultural production potential (Phipson, 2012).

UMsinga is semi-arid, mostly receiving less than 400 mm rainfall per annum (Cogta, Province of KZN, 2011). However Letty, (2007) argued that the driest areas in uMsinga are seen to fall into the 503 – 550 mm category. It is located at latitude 28° 44' 56.4" and longitude 30° 26 ' 33.36" under UMzinyathi district. The altitude ranges from 406 m to 1635 m (Letty, 2007). The erratic nature of the rainfall in most of uMsinga makes it risky to invest in crop production where supplementary irrigation is not available. The natural vegetation ranges from grassland on higher altitude areas where the rainfall is higher and temperatures cooler (Letty, 2007; Institute of Natural Resources, 2007), while valley bushveld is located in the hot, dry, low lying valleys; and mixed thornveld lies between these two extremes (Institute of Natural Resources, 2007). During winter, the area experiences frost which has a negative impact on crop productivity. A study by Letty (2007) revealed that most crops cultivated by communal uMsinga farmers were drought tolerant millet, dry beans, maize, sorghum and groundnuts. Nguni cattle and goats are common livestock kept here, due to their ability to tolerate high temperatures, low rainfall and both thornveld and grassland vegetation. UMsinga soils have mostly low to moderate productive potential due to problems of high erosion hazard, shallow depth and very poor drainage (Institute of Natural Resources, 2007). According to Nyiraruhimbi, (2012), uMsinga is dominated by Mispah, Glenrosa and Milkwood which are all shallow soils. Traditional authorities play an important role in terms of controlling access to land for housing and agricultural purposes, thus local farmers in uMsinga are organised into associations and co-operatives (Letty, 2007). These structures are further organised into umbrella bodies at district level and individual farmers have options to affiliate to either the local or the district structures.

3.2.2 Experimental design and sampling procedure

The study was carried out in eight villages from each of uMsinga and Bergville, giving a total of sixteen villages in all. Information was gathered through interviews with key-informants, then focus group discussions and a household questionnaire (Appendix A.1) with farmers. In each area 5 key informant interviews and 8 focus group discussions were done, while 25 household questionnaires were administered per village. Each focus group comprised 10 to 15 individuals. In all, 400 questionnaires were administered in the sixteen villages of both areas. All primary and secondary sources were acknowledged to avoid plagiarism.

The triangulate research methodology was used, which utilises two or more different kinds of tools to validate the reliability of information obtained (Grace *et al.*, 2013). In the study, I captured qualitative data from informal interviews and discussions, while the quantitative data was obtained via a household questionnaire. Farmers from both areas were randomly selected, based on their availability and willingness to participate; with all ages and both genders considered. The language of communication was the IsiZulu local language, which was familiar to all participants. The duration of interviews was 60 to 90 minutes. To avoid invasion of privacy, we chose not to probe too deeply into the private life of respondents concerning issues such as financial status and religious affiliations. Questions pertaining to the interviews were listed on the informed-consent sheet that each interviewee signed. In addition to respecting the privacy of the respondents, we ensured their anonymity. Participants were also given the choice of withdrawing from the study whenever they felt that they do not wish to participate. Ethical issues such as permission, anonymity, consent and confidentiality were sort before the survey commenced. All respondents were assured that the information collected would be used for the purpose of the research.

3.2.3 Data collection and methodological tools

Both primary sources (data from local farmers) and secondary sources (data from literature) were used to generate information for the study. The literature review played a pivotal role to get background information about the hydrology, biophysical features, land type and ownership, soil and soil water, vegetation, agriculture and climate of the study sites. Climatic data was sourced from weather stations, with the department of Agriculture providing most of the necessary information about the climate, type of farming and the way of living in both Bergville and uMsinga. KwaZulu Natal bioresource units (BRUs) indicated areas experiencing difficulties in coping with climate variability.

3.2.3.1 Key informant interviews (KIIs)

Five key informant interviews (KIIs) were conducted in each study area, giving a total of ten key informants altogether. KIIs aimed at identifying the main agricultural activities and natural resource management strategies practiced in the research areas. Different KIs from community leaders, extension workers, researchers, social workers to various government officials were chosen from each area. The interviewees included an official from the Department of Social Development and Meteorological station in Bergville and uMsinga respectively, to capture expert opinion on the observed climate of the area. Agricultural extension workers of the two regions discussed on land use, type of farming, measures implemented to improve production and reduce land degradation. Scientific views from personal from Water Research Commission and Regional Forestry were also solicited. The chief was interviewed in uMsinga as one of the key informants while community leaders (Figure 3.2), who are also farmers, were included in both districts to get perspective on their experiences. The responses obtain from the KIs gave good background knowledgeable of the study areas that served as a basis for more detailed studies.

Figure 3. 2: Key Informant, Gog'uMadlala, from Enhlesi village in uMsinga.

3.2.3.2 Focus Group Discussions (FGDs)

A total of eight villages were selected from each district for this study, with one FGD being conducted in each of these villages, giving sixteen FGDs in all. Eight villages were chosen randomly in Bergville namely Busingatha, Obanjaneni, NewStands, Okhombe, Reserve B, Potshini, Mlimeleni and Okhombe. While in uMsinga the eight villages were Fabeni 1, Fabeni 2, Gudwini, Enhlesi, Nocomboshe 1, Nocomboshe 2, Nocomboshe 3, and Machunwini. Each FGD comprised 10-15 individuals of mixed gender and age groups. According to Zuma--Netshiukhwi *et al.,* (2013), FGDs allow a good platform for interacting with farmers from different backgrounds and to exchange knowledge. The aim of the discussion was to get qualitative information about soil and water conservation, land uses, design of the agricultural system, climate knowledge and the role played by communal farmers in preserving soil and water. All the FGDs were organised by the community leader of that particular village. Open-ended questions were asked in the discussions, and every person was allowed to express their views. A list of available coping strategies to climate variability used by each households in the community was also documented during the FGD. Figures 3.3 and 3.4 below depict some of the focus group discussions done at Bergville and uMsinga respectively.

Figure 3.3: Focus group at uBusingatha village in Bergville

Figure 3. 4: Focus group at Machununwi village in uMsinga.

3.2.3.3 Baseline Survey

After the KIIs and FGDs were concluded, in-depth interviews with a structured questionnaire (Appendix A.1) were then done on individual farmers to get more specific information. The interviews targeted 200 respondents per district, with a total of 25 respondents randomly selected from each village. The questionnaires were administered through face-to-face interviews using the native language isiZulu. Participation was voluntary, so no one was forced to answer questions that were sensitive for them. A total of 400 questionnaire were administered altogether, with all participants being locals well informed about traditional beliefs in the area, methods of planting, climate variability trends and indigenous methods employed to deal with climate variability, soil and water conservation.

3.2.3 Statistical Analysis

All data was analysed for variability using the SAS Institute Inc. 9.3 statistical package (2008). Gender, age, agricultural training and trend of climate change over the years were analysed using PROC FREQ of SAS Institute Inc.9.3 (2008). The questionnaire responses was manually transfer into a spreadsheet. Each possible answer was assigned a number or code, depending on the frequency of use. Thus the response used often was assigned number 1, with any response higher than this number indicating a decrease of use. The PROC GLM procedure was used to analyse the understanding of climate variability, farm systems structure, indigenous indicators, indigenous methods used to conserve soil and water and comparisons between indigenous and scientific ways used to conserve water and soil.

3.3 RESULTS

3.3.1. Demographic and agricultural systems information

Table 3.1 shows that there were more female than male farmers in both areas, with uMsinga (81.8 %) having a higher number of females than Bergville (72.8 %). Bergville however had a higher percentage of male farmers (27.2%) than uMsinga (18.2%). Over 70 % of the respondents interviewed in both districts affirmed that they actively practiced both arable cropping and livestock farming, though their levels of training in agricultural production varied. Almost 61% of farmers received some form of agriculture training in uMsinga, while 48 % of the farmers were trained in Bergville. These training were offered by several organisations. Farmers Support Group (FSG) for example, from UKZN trained farmers from both areas in adapting zero tillage, stone terraces, compost preparation, use of raised beds, planting potatoes in bags, ridge/furrow planting, manure addition, water recycling, rotational grazing and also introduced new cultivars of yellow maize with higher yields. Land care trained farmers in Bergville on zero tillage and contour ploughing, while in uMsinga the Department of Agriculture introduced farmers to zero tillage and terraces. Philakahle, an NGO, trained farmers in Bergville on processing and commercialisation of agricultural products. LIMA, FSG and the Department of Agriculture in both areas gave farmers general knowledge on agriculture and encouraged them to take soil samples for fertility testing. Water Trust, DWARF and Grain SA gave farmers water tanks and trained them on water preservation and recycling. Generally, training on soil and water management was higher in Bergville (75 %) compared to uMsinga (57 %). The majority of farmers in both areas (99 %) believe that the climate is changing, through increasing temperatures, declining rainfall and changing rainfall patterns. As a result, most of them expressed a keenness to adopt soil and water conservation techniques offered by research and science i.e. 92 % from Bergville and 84 % from uMsinga respectively, (Table 3.1).

Table 3. 1: Demographics of communal farmers in Bergville and uMsinga area and their participation in farming activities.

Variable	% of farmers in Bergville	% of farmers in uMsinga
Male	27.2	18.2
Female	72.8	81.8
Agricultural training	48.0	60.5
Residing on Farm	100	100
Engagement in farming activity	79.4	82.2
Belief in climate variability	99.0	99.5
Training on S & W management	75.0	57.5
Keenness to adopt SWCT from science	91.9	84.2

SWCT- Soil Water Conservation Technique

S & W- Soil and Water

3.3.2 Sources of income for farming communities

There were various sources of income in Bergville and uMsinga, ranging from crop or livestock farming, home industries, poultry farming, wages and social grants (Table 3.2). The values in Table 3.2 show the means of sources of income with lower values being the most common and higher values being the least used. In both areas communal farmers rely mostly on crop farming for survival. The selling of surplus crop after harvest and barter trade of crops for either livestock or clothes also happens. Home industries such as making of reed mats, pottery and sculptures were the second source of income in both areas. In uMsinga livestock farming was the third source of income, followed by wages, social grants and lastly poultry farming. However in Bergville, wages were the third source of income, followed by livestock farming, social grants then poultry farming. There was a significant differences between Bergville and uMsinga farmers on social grants ($p = 0.003$) and poultry farming ($p = 0.01$), with uMsinga having fewer farmers relying on both sources of income that Bergville (Table 3.2).

Table 3. 2: Sources of income for Bergville and uMsinga farmers

Source of Income	Bergville	uMsinga	Significance ($p < 0.05$)
Crop farming	1.2	1.2	0.86
Livestock	1.7	1.5	0.36
Home Industries	1.4	1.5	0.91
Poultry farming	1.7	2.7	0.01
Salary/Wages	1.6	1.7	0.57
Social grants	1.6	1.9	0.003

*Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Values in the table represent the means of sources of income with lower values being the most common and higher values the least used

3.3.3. Types of crops that are currently grown by communal farmers

The sequence of crops that are grown in uMsinga ranging from the most grown to the least then followed the order vegetables > maize > potatoes > sugar beans > sorghum > pumpkin > soybeans; whiles in Bergville it was maize > potatoes > vegetables > sugarbeans > sorghum > pumpkin >soybeans (Table 3.3). In both areas soybeans, pumpkin and sorghum proved to be not so popular.

Table 3. 3: Crops are current cultivated in Bergville and uMsinga.

Crops	Bergville	uMsinga	Significance ($p<0.05$)
Maize	1.1	1.2	0.68
Sugar beans	1.5	1.8	0.16
Potatoes	1.2	1.2	0.87
Pumpkin	2.5	2.8	0.14
Sorghum	2.4	2.3	0.66
Soybeans	3.3	3.6	0.20
Vegetables	1.4	1.1	0.11

*Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Values in the table represent the means of crops with lower values being the most common and higher values the least cultivated

3.3.4. Challenges faced by farmers in crop farming

The greatest challenge to farming in uMsinga was erratic rainfall patterns followed by low soil fertility (Table 3.4). In fact, more farmers in uMsinga than Bergville believe erratic rainfall patterns seriously hamper crop production ($p = 0.001$). Poor soil fertility on the other hand was a greater challenge for Bergville farmers. It was also cited as the second common challenge in uMsinga, while Bergville farmers expressed that high prices of commercial fertilizers also hindered their crop production. Other challenges to crop production given were the lack of tenure by most farmers or crop losses due to pests and diseases. Limited labour did not appear to be a big issue in both areas however (Table 3.4).

Table 3. 4: Challenges faced by Bergville and uMsinga farmers in crop farming.

Challenge	**Bergville**	**uMsinga**	**Significance ($p < 0.05$)**
Poor soil fertility	1.7	1.6	0.19
Fertilizer prices	2.0	2.2	0.14
Erratic rainfall	2.0	1.4	0.001
Limited labour	2.4	2.5	0.70
Land tenure	2.4	2.0	0.38
Pests/diseases	2.3	2.1	0.23

*Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Values in the table represent mean scores of challenges with lower values being the most common and higher values the least challenges

3.3.5. Coping strategies to limited water supply

Table 3.5 shows the copping strategies that farmers in Bergville and uMsinga use to cope with limited water availability. The sequence of coping strategies in Bergville from the most adopted strategy to the least used were: use of drought resistant crops > conservation tillage techniques > changing planting density > crop rotation > mixed cropping > planting early maturing crops > use of drought resistant cultivars > revising the planting date. In Bergville, drought resistant crops grown include sorghum, millet and dry bean; while conservation tillage techniques used are no-till or fallowing. Planting densities are usually intensified to increase plant survival rates during drought years. When rainfall is erratic, Bergville farmers also enhance food security by using crop mixtures, e.g. maize is intercropped with soybean, marijuana and / pumpkin in the field. Yellow maize cultivars are also adapted in some cases since they are more drought tolerant than white maize cultivars. A few farmers also rotate their maize with soybeans or wheat, while vegetables and some horticultural produce (beetroot, tomatoes, onions, pepper etc.) are grown in gardens with supplementary irrigation throughout the year.

The sequence of coping strategies in uMsinga from the most to the least adopted strategy followed the order: changing planting density > use of drought resistant cultivars > conservation tillage techniques > drought resistant crops > crop rotation > early maturing crops > mixed cropping > revising planting date (Table 3.5). The reasons for use of these strategies are more or less the same as those given by Bergville farmers. However, uMsinga farmers further grow small leaf - sized spinach, which is more drought tolerant than the normal leaf sized one. The use of drought resistant cultivars was actually a more common adaptation strategy in uMsinga than Bergville ($p = 0.002$). Furthermore, uMsinga farmers practice zero tillage, fallowing, contour ploughing and use raised beds (in gardens) to preserve the limited moisture. Drought resistant crops such as sorghum and dry bean are also common; while field maize is rotated with soybeans, and vegetables are prominent in gardens in uMsinga (Table 3.5). Vegetables have the advantage that they are early maturing and can be grown throughout the year in small gardens with supplementary irrigation during the dry season. More farmers in uMsinga than Bergville actually use early maturing crops as a strategy to cope with reduced water supply ($p = 0.04$). The revision of planting dates to align with the shifting rainy season was the least used coping strategy in both areas.

Table 3. 5: Coping strategies adopted to cope with limited water availability.

Coping Strategy	Bergville	uMsinga	Significance ($p<0.05$)
Drought resistant cultivars	2.0	1.1	0.002
Drought resistant crops	1.3	1.3	0.84
Early maturing crops	1.9	1.6	0.04
Crop rotation	1.5	1.6	0.86
Mixed cropping	1.7	1.6	0.52
Revising planting dates	2.3	2.9	0.90
Changing plant density	1.5	1.0	0.67
Conservation tillage	1.5	1.2	0.23

*Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Values in the table represent the means of coping strategies with lower values being the most common and higher values the least used

3.3.6. Types of crops that were cultivated in the past by farmers

Table 3.6 shows that sorghum was the most popular crop which was cultivated in the past in both areas, though more farmers in uMsinga than Bergville were cultivating it ($p = 0.05$). The sequence of crops that were grown in the past in uMsinga ranging from the second most grown to the least then followed the order sunflower > sweet potato > cowpeas > round nuts > sweet cane > groundnuts; whiles in Bergville it was sweet potato > round nuts > sweet cane > sunflower > groundnuts. In Bergville, both groundnut and sunflower proved to be equally unpopular in the past.

Table 3. 6: Crops which were cultivated in the past in Bergville and uMsinga.

Crops	Bergville	uMsinga	Significance ($p<0.05$)
Sorghum	1.5	1.3	0.05
Groundnuts	2.3	2.8	0.13
Sweet cane	2.2	2.5	0.11
Round nuts	2.2	2.3	0.15
Cowpeas	2.4	2.3	0.66
Sunflower	2.3	1.6	2.66
Sweet potato	1.9	1.6	0.15

*Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Values in the table represent the means of crops with lower values being the most common and higher values the least cultivated

3.3.7. Challenges faced by farmers in livestock or poultry rearing

Table 3.7 shows the challenges faced by Bergville and uMsinga farmers in livestock or poultry farming. Poor quality breeds, in terms of milk and meat production, was the most prevalent challenge faced by farmers, followed by the problem of inadequate local feed supply in both areas. In Bergville the third challenge was that of livestock thefts, with a high proportion of farmers in this area noting this as a huge challenge compared to those in uMsinga ($p = 0.001$). The next challenge in Bergville was that of high prices of commercial feed, followed by outbreaks of pests and diseases then limited water supply for the animals, poor access to markets and finally the problem of limited labour. In uMsinga the third most prominent challenge was limited water supply followed by the higher prices of commercial feed, the outbreaks of pests and diseases then livestock thefts. Both poor access to markets and limited labour did not seem to be huge challenges for uMsinga farmers. Differences also existed in viewpoints between Bergville and uMsinga farmers in terms of challenges of inadequacy of local feed ($p = 0.01$) and limited water supply ($p = 0.001$); with more farmers in uMsinga expressing stronger concerns of these challenges than those in Bergville.

Table 3. 7: Challenges communal farmers face in livestock/poultry farming.

Challenges	Bergville	uMsinga	Significance ($p<0.05$)
Poor quality breeds	1.7	1.0	0.42
Inadequate feed supply	1.9	1.6	0.01
High prices of commercial feed	2.4	2.2	0.47
Limited water supply	2.5	2.1	0.001
Pests and disease outbreaks	2.4	2.3	0.33
Limited labour	3.2	4.0	0.58
Limited access to markets	3.2	4.0	0.87
Theft	1.9	2.5	0.001

*Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Values in the table represent mean scores with lower values being the most common and higher values the least common challenges

3.3.8. Perceptions by farmers on the state of their climate.

Table 3.8 shows climate variables used by farmers in understanding their climate. In both areas, rising temperatures was the most observed indicator of climate variability with more farmers in uMsinga asserting that they have been experiencing temperature rises ($p = 0.05$). Reduced rainfall was the second indicator observed in both areas, but more farmers in Bergville than uMsinga use this as an indicator of climate variability ($p = 0.02$). Other climate variability indicators observed in Bergville then followed the sequence of: change in rainfall pattern >

change in length of planting growing season > change in rainfall intensity > change in wind patterns. However in uMsinga, the sequence of climate change indicators then became: change in rainfall pattern > change in planting growing season > change in wind patterns > change in rainfall intensity (Table 3.8). There were differences however in the perceptions of framers from the two areas in terms of some of the climate variability indicators, since more farmers in Bergville assert higher changes in rainfall patterns (p = 0.03) than those in uMsinga.

Table 3. 8: Climate variability indicators used to assess the climate by farmers.

Variability indicator	Bergville	uMsinga	Significance (p<0.05)
Rising temperatures	1.6	1.5	0.05
Reduced rainfall	1.7	1.8	0.02
Change in rainfall pattern	2.5	2.8	0.03
Change in rainfall intensity	2.8	3.2	0.09
Change in plant growing season	2.7	2.9	0.48
Change in wind patterns	3.3	3.2	0.38

*Where p < 0.005, it means there are significant differences in that parameter between the 2 areas

Values in the table represent the means of indicators with lower values being the most common and higher values the least used

3.3.9. Sources of information that inform farmers on climate patterns

According to Bergville and uMsinga farmers, the media, agricultural advisors, IKS holders and community leaders serve as sources of climate information, though there are a few contradictions on their reliability (Table 3.9). In Bergville the media, characterised by radio, TV and print, is the most common source of climate information used. Secondly, IKS holders (traditional healers and rainmakers) and indigenous indicators are also a good source of climate information in Bergville. These were then followed by organisations like FSG and Philakahle, then community leaders which comprised the chief and pastors. The least reliable source of information in Bergville was from agricultural advisors from government. On the other hand, the most reliable source of climate information in uMsinga is IKS holders and indigenous indicators (animal and insect behaviour, wind and cloud patterns). This was followed by the media especially radio. The third widely ued source of climate information in uMsinga was agricultural advisors from the department of agriculture and water affairs, followed by organisations such as FSG and Sinozwelo, and lastly community leaders. There significant differences in use of the media and IKS between Bergville and uMsinga; with the media being used more in Bergville while IKS was used more in uMsinga ($p < 0.001$ in both cases).

Table 3. 9: Climate information sources used in Bergville and uMsinga

Information	Bergville	uMsinga	Significance ($p<0.05$)
Media	1.42	1.66	0.001
Agricultural advisors	2.1	1.88	0.45
Community leaders	1.8	2.29	0.23
IKS holders	1.65	1.38	0.001
NGOs	1.72	2.0	0.65

IKS- Indigenous Knowledge System. *Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

NGOs- Non- Governmental Organisations.

Values in the table represent the means of sources with lower values being the most common and higher values the least used

3.3.10. Indigenous indicators that are in place to predict the weather.

The most used indigenous indicator to predict weather in Bergville was animal behaviour, particularly cattle that get very excited and start running and jumping around before the rain falls (Table 3.10). More farmers in Bergville than uMsinga use animal behaviour as a quick indicator of the weather ($p < 0.03$). The sequence of most used indicators in Bergville starting from the second best used to the least used then followed the order: bird behaviour > sun formation > wind patterns > insect indicators > cloud patterns > stars > the shape of the moon (Table 3.10). In uMsinga the order of indigenous weather indicators was: bird behaviour > cloud patterns = animal behaviour > sun formation > insect behaviour > wind patterns > moon shape. Usually when birds such as amahlolamvula (*Apus apus*), inkonjane (*Hirundu rustica),* and isingizi/ingududu (*Buceros birconis*) fly low and form formations, it shows pending rain. More farmers in uMsinga than Bergville actually rely on bird behaviour as a rain indicator ($p < 0.01$). Huge dark clouds are also believed to bring heavy rains, more so in uMsinga than Bergville ($p < 0.001$). Whenever they are dark lines surroundings the sun communal farmers believe that rains are pending. Communal farmers believe that when there are many stars in the sky, it will be a drought year. Whenever there is an outbreak of insects (ants and grasshoppers), it indicates pending drought, pests and disease outbreaks in the coming season. In uMsinga, farmers believe strong winds blowing from South west to north east bring rains. When the moon is half shaped and facing downwards, IK holders in Bergville believe it will rain within a few days. On the other hand when the moon is either full or half shaped and facing upwards, it will not rain. In uMsinga farmers say that when the moon is facing Swaziland (i.e. westward), it brings more rain. The shape of the moon was used more in uMsinga than Bergville ($p = 0.04$, Table 3.10).

Table 3. 10: Indigenous indicators used to predict weather in Bergville and uMsinga.

Indigenous Indicator	Bergville	uMsinga	Significance ($p<0.05$)
Animal behaviour	1.31	1.9	0.03
Bird behaviour	1.82	1.48	0.01
Insect Indicators	2.46	2.17	0.20
Wind patterns	2.28	2.36	0.53
Stars	2.71	2.33	0.47
Cloud patterns	2.6	1.9	0.001
Moon shape	2.9	2.47	0.04
Sun formation	2.25	2.03	0.53

*Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Values in the table represent the means of indicators with lower values being the most common and higher values the least used

3.3.11. Indigenous and scientific techniques utilized by farmers to conserve soil and water

Indigenous techniques used to preserve water and soil in the two areas were rain water harvesting, construction of earth dams, wells, addition of manure, contour farming and fallowing (Table 3.11). While rain water harvesting, mulching, zero tillage, furrow/ridge planting, minimum tillage, cover crops, terraces (using stones), raised beds and green manuring were conserving technique adopted from science. Rain water harvesting is considered both IKS and science based because of the different perceptions of farmers. In both areas both during focus group discussion and base line survey communal farmers would thoroughly argue on which side does the rain water harvest belongs hence both systems were catered. Table 3.11 shows that most of indigenous techniques were used in fields, while science techniques were mostly implemented in garden. Soil and water conservation techniques used in fields were rain water harvesting, manure addition, earth dams, contour farming, fallowing, cover crops and terraces. Rain water harvesting, mulching, animal manure, furrow/ridge planting, crop residue mulch, raised beds, green manuring and wells were used more in gardens. Rain water harvesting for gardens and household use was the most common indigenous water preservation method used in both areas, but more so in uMsinga ($p < 0.001$). Rain water for household use was harvested from gutters on the roofs using buckets, whereas in the field it was harvested through constructed furrows. Water conservation practices in Bergville then followed the order: wells > earth dams > animal manure > ridges & furrows > contour ploughing > green manuring > fallowing > cover crops > crop residue mulch > raised beds > terraces. In Bergville, earth dams were constructed down a river or stream to trap water for household use, arable cropping and in gardens. The manure added was from cattle and goat, and it was used in both fields and gardens. Ridges and furrow were mostly used in gardens to trap water or re-route excess water away from the plants. Bergville farmers also practice green manuring in some instances, by ploughing under their soybean crop. Farmers have different perceptions in fallowing with few practising it as a conservation strategies and majority do it due to farming abandonment, as a result of challenges like expensive fertilizers and seeds or the absence of tractors for ploughing. Cover crops that were used were soybean, sugar bean and peas. Mulching is mostly done using crop residues. Terraces, though not very popular in both areas are sometimes used for land rehabilitation, by lining up stones across the slope to minimise runoff and erosion. This is a more common practice in uMsinga than in Bergville ($p = 0.04$). Table 3.11 shows the science techniques used in uMsinga to preserve soil and water with sequence from most used to least as follows: rain water harvest > furrow/ridge planting > soybean green manure > soybeans cover crop > raised bed > terraces. In uMsinga, the order of conservation practice (IKS) used after rainwater harvesting was, animal manure > wells and earth dams > contour farming > grass and crop residue mulch > fallowing. Mulching is a more common practice in uMsinga than Bergville ($p < 0.001$).

Table 3. 11: Techniques used to preserve soil and water in Bergville and uMsinga.

Preserving Strategies		Bergville	uMsinga	Significance ($p<0.05$)
SCIENCE	**IKS**			
Rain water harvest	**Rain water harvest**	1.58	1.11	0.001
	Earth dams	2.0	2.0	1.00
	Wells	1.93	2.0	0.76
	Adding manure	2.10	1.96	0.11
	Contour farming	3.14	2.94	0.34
	Fallowing	3.65	3.27	0.40
Mulching		4.08	3.20	0.001
Furrow / ridge		2.74	3.73	0.01
Terraces		6.04	5.18	0.04
Cover crops		3.67	2.4	0.05
Raised beds		4.54	4.92	0.12
Green Manure		3.62	2.0	0.12

*Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Values in the table represent the means of techniques with lower values being the most common and higher values the least used

3.3.12. Perception by farmers on how the various indigenous and science conservation techniques affect crop yields, soil fertility as well as soil and water conservation.

Table 3.12 shows the results of how farmers rank the performance of the different indigenous techniques in terms of crop yields, soil fertility improvement and soil water conservation. Indigenous techniques ranked were manure application, contour ploughing, furrows, well/earth dams and rain water harvesting. Farmers from both areas believe that these techniques are most effective at preserving soil and water, and this was more so in uMsinga than Bergville ($p < 0.001$). Yield improvement was the second best perception of the techniques by farmers, particularly in uMsinga ($p < 0.001$). Farmers from both areas, particularly uMsinga, ($p = 0.01$), believe that the IK techniques were least likely to enhance soil fertility.

Table 3. 12: Perceptions of how farmers rank the performance of indigenous techniques (manure addition, contour ploughing, rain water harvest and earth dams) in conserving S & W, improving yields and enhancing soil fertility.

Output	Bergville	uMsinga	Significance ($p<0.05$)
Crop yield improvement	1.5	1.2	0.001
Soil fertility enhancement	1.5	1.2	0.01
S & W conservation	1.4	1.1	0.001

S & W- soil & water conservation. *Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

Table 3.13 shows the output of how farmers perceive scientific techniques to affect soil fertility, crop yields, and soil and water conservation. The science techniques considered here were fertilizer application, zero tillage, water storing tanks and stone terraces. Farmers' perceptions on performance of these techniques followed the order fertility enhancement > crop yield improvement > soil & water conservation in Bergville; but was soil fertility enhancement > soil & water conservation > crop yield improvement in uMsinga. There was a significant difference of farmers' perception on soil and water conservation with uMsinga farmers believing that science techniques enhance it more than Bergville farmers ($p < 0.01$).

Table 3. 13: Perceptions of how farmers rank the performance of scientific techniques (fertilizer, zero tillage, tanks and terraces) in conserving S & W, improving yields and enhancing soil fertility.

Output	Bergville	uMsinga	Significance ($p<0.05$)
Crop yield improvement	1.5	1.4	0.21
Soil fertility enhancement	1.2	1.1	0.15
S & W conservation	1.5	1.2	0.01

S & W- soil & water conservation. *Where $p < 0.005$, it means there are significant differences in that parameter between the 2 areas

3.4 Discussion

Most households in Bergville and uMsinga are female-headed. This is due to migration of males to urban areas in search for employment. Walker and Schulze (2006), also discovered that many small-scale farmers in the Bergville were women. About 70-80 % of village production in sub Saharan Africa is predominated by female farmers (Boserup *et al.,* 2007). In South Africa, three-quarters of the poor live in rural areas with rural households headed by women being among the most impoverished (Ministry of the Office of the President, 1995). The decline in rainfall and increase in temperatures also force local farmers to abandon agriculture. This was similar to the observation of MacKella *et al.,* (2014) who discovered significant increases in temperatures in KZN for all seasons which ranged from 0.015 °C/year to 0.027 °C/year.

A major challenge in Africa is how to reconcile indigenous knowledge with modern science (Domfeh, 2007). Farmers in uMsinga (60%) have received more agricultural training on how to rear superior livestock breeds which are resistant to harsh climates, or diversify farming by adding vegetable gardens to their traditional maize compared to Bergville (48%). Government institutions (Department of agriculture) and NGOs (FSG and Sinozwelo) offered agricultural training to farmers in drought stricken uMsinga, so as to prevent starvation. Sotshongaye & Moller, (2010) discovered that community gardens at Ndwendwe, KwaZulu Natal, were doing well, especially after communities received training on mulching, using raised beds and irrigation to increase crop production throughout the year. Though Bergville has been experiencing more erratic rainfall over the years, farmers in this area harvest enough food for consumption. An investigation of farmer's adoption showed that demographic variables, technological advancement, farmer knowledge and group influence have an impact on farmer's adoption of a new innovation (Thomas *et al.,* 2007). More farmers in Bergville received training in soil and water conservation compared to uMsinga. This is because there are more governmental organisations (Department of Agriculture's DWARF), agricultural extension workers and NGOs such as Land care, Philakahle, Farmer support group (FSG), Water trust and Grain SA in Bergville who prioritize soil and water conservation, compared to uMsinga which had only the Department of Agriculture, Institute of Natural Resources (INR), FSG and Sinozwelo working in the area. It might also be that farmers in uMsinga do not readily adopt the strategies after training since they do not have the finances, labour and support structures to sustain them.

Bergville and uMsinga farmers rely on crop and livestock farming, home industries, poultry farming, salary and social grants for income. According to Shackleton *et al.,* (2010) livestock and crop production make significant contributions to rural livelihoods in South Africa. Sotshangaye and Moller (2007) discovered that farmers in Ndwendwe, South Africa survived on pension, agricultural production and products from trading. Crop farming was the best source of income in both Bergville and uMsinga, because they have been practising it for ages and possess the skills to accomplish it. This was concluded through farmers' perception who believed that they most important expertise they possess is crop farming and livestock rearing. Rainfall is the limiting factor to most crop production. Home industries such as making of reed mats, pottery and sculpture were the second source of income because many people were good at crafting and take it as a hobby. According to Sotshangaye and Moller, (2007), the source of income varies considerably from region to region depending on resource availability, institutional controls, population densities, employment and income levels, availability of alternatives, personal and cultural preferences. Unemployment is escalating, thus very few farmers have seasonal jobs mostly in commercial farms; hence social grants make a huge contribution to rural livelihoods. In a study by Sotshangaye and Moller, (2007) in KZN, none of the women interviewed had formal employment but survived on pension, agricultural production and profits from trading. Poultry generated very little income since almost everyone in the villages had chickens making it difficult to market. Livestock generated less income than crop farming, home industries and social grants. This may be attributed to inferior animal breeds and poor quality feed leading to low meat and milk production. Nguni cows in Bergville and uMsinga graze freely, without any supplementary feed and sometimes suffer from water shortages or overgrazing due to absence of rotational grazing. They produce roughly 2 - 4 litres of milk per day compared to commercial breeds which produce 10 – 20 litres under improved conditions (Moyo, 1996). The low milk production is further exacerbated by fewer lactating cows under communal farming (Musemwa *et al.*, 2008). Bergville and uMsinga farmers say temperatures have been increasing and rainfall declining over the years. Reid & Vogel (2006) also observed that KZN was experiencing multiple climate stresses such as droughts, floods, thunderstorms and lightning, which negatively impact agricultural production. In uMsinga, summer temperatures have been increasing such that animals struggle to graze and can hardly be used for drought power. The Institute of Natural Resources - INR, (2007) also noted that higher temperatures reduced quality and time of grazing for cattle, causing them to spend more time under the shed during the day. INR (2007) stated that the low and erratic rainfall in most of uMsinga which ranges from 503 – 550 mm annually, makes it risky to invest in crop production where supplementary irrigation is not available.

Reduced rainfall and higher temperatures have forced farmers to divert from crop to livestock farming because indigenous livestock cope better under dry weather. Erratic rainfall and high incidence of droughts in most rural areas of South Africa, influence resource-poor farmers to depend on livestock farming (Musemwa *et al.,* 2008). However poor quality breeds remains a challenge to rural farming. Superior exotic breeds such as the Jersey cow which produces more milk than Nguni, fail to cope with the harsh weather, disease outbreaks, scarce feed and poor management characteristic of communal areas (Collins-Luswet, 2000). Bayer *et al.,* (2004) noted that high yielding Jersey or the beef cattle Holstein that need high quality feed, had difficulties in coping with high temperatures of rural KZN, coupled with a higher susceptibility to many diseases which caused higher production costs. Musemwa *et al.,* (2008) also observed that high milk yield or high growth rates and adaptation to a difficult environment were antagonists. Nguni cattle could dominate the beef market due to their adaptability to the local climate if feed supply is improved. Low meat production means that communal supplies are unable to cope with high demand for naturally produced beef (Musemwa *et al.,* 2008). Our study revealed that Bergville and uMsinga farmers were less concerned about markets since they rear livestock for wealth status, milk, meat, hides, horns, manure, draught power and as insurance in case of emergency. Livestock rely on free grazing and are fed on plant residues during winter. Perennial rivers are the main sources of water for livestock especially uThukela river which originates in Bergville, through Drakensberg mountain and flows to uMsinga. Livestock theft is a major challenge in Bergville, with farmers believing that the perpetrators originate from Escourt, Mnambithi and neighbouring Lesotho. Musemwa *et al.,* (2008) also noted that the lack of marketable livestock in most rural areas was a result of livestock thefts. Good prices offered for Nguni cattle further increase theft cases from this breed (Dzimba and Matooane, 2005). Pests and disease, for both animals and plants, are usually treated with ash or local herbs such as the aloe. Wounds are washed and smeared with cow dung. Culling of animals is only employed as a last resort, especially where the disease is rampant.

Challenges faced by Bergville and uMsinga farmers are attributed to natural and socio-economical causes. The apartheid government pushed communal farmers to hilly less fertile land, thus poor soil fertility was a challenge in both areas. Dlamini *et al.,* (2011) saw that poor soil fertility in Bergville was caused by sheet erosion and leaching of nutrients. According to Livingstone *et al.* (2011), smallholder farming is practised on land that is ≤ 2 ha. This was similar to the study areas where mostly household had less than 1 ha of the land. The communal land rights bill of 2000 also gave land rights to traditional leaders instead of individual farmers (Ntsebeza, 2003), making land tenure a problem since most communal farmers do not have title. Erratic rainfall also poses as a challenge to farming, particularly in arid uMsinga leading to serious water shortages. Most farmers in KZN say they need piped water for household use and supplementary irrigation for farming due to low water supply (Sotshangaye and Moller, 2007). Limited labour, expensive commercial fertilizers and pests/diseases also hinder crop production. Farmers from both areas supplement commercial fertilizers with cattle and goat manure to improve fertility. Most of the households in both areas have enough family members to work in the field so outside labour is not usually required.

Among the climate variability indicators used, stronger winds were the least observed parameter of climate variability in both areas, as only those farmers residing on upper slopes experienced it. Perceived changes in rainfall patterns and intensities were different in the two districts. More farmers in Bergville noticed a change on the onset of rain, which now starts in late November instead of late September making the rainy season shorter. In uMsinga farmers believe their region has always been dry, so it was difficult for them to attribute rainfall as an indicator for climate variability. Zindove and Chimonyo, (2015) also noted that uMsinga was semi-arid, characterised by erratic rainfall and large diurnal temperature ranges, with highest mean monthly maximum temperature of 37 °C in January. Farmers in uMsinga foresee more severe droughts in the near future, with rainfall events becoming shorter and more intense than before. Joubert and Mason, (1997), also suggest that drought and other extreme events have become more severe and more frequent in both areas.

The use of drought tolerant cultivars, farm diversification, early planting, intercropping and crop rotation were some of the strategies used by farmers to cope with dry weather. They now prefer yellow instead of white maize varieties, believing them to withstand the drier climate. More farmers in uMsinga practice crop rotation than in Bergville as a coping mechanism to low water supply. Maize, potatoes, wheat and soybeans were rotated in the field, while cabbage, onion, spinach, beetroot and tomatoes were rotated in the gardens. In both areas many farmers practised maize monoculture during summer and vegetable gardens in winter. Farmers in Bergville have diversified to marijuana because of its high market value while uMsinga farmers also rear horses and donkeys due to their drought resistance and use as draught power. Bergville farmers intercrop maize with soybeans or marijuana while in uMsinga maize is intercropped with soybeans or pumpkins. Farmers utilise different sources of climate information depending on their reliability. Generally reliable sources of climate information in both areas are the media, IKS (traditional healers and rainmakers) and NGOs such as Sinozwelo (in uMsinga), Philakahle (in Bergville) and FSG (in both areas). There is more use of the media in Bergville, while IKS is a more reliable climate information source in uMsinga since they have limited access to television, radio, internet and print media. Infrastructural development is lower in uMsinga, as many villages are still without electricity compared to Bergville. Electricity supply in uMsinga is mainly restricted to schools, clinics and the settlements of Keates Drift, Tugela Ferry or Pomeroy (INR, 2007). Most communities depend on wood, paraffin and gas energy, i.e. 92% of respondents in a 2001 Census (INR, 2007). Community leaders and agricultural advisors are also another source of climate information, with the former being used more in Bergville and the later in uMsinga. Given the unfavourable climate in uMsinga, the government has tried to assign more agricultural advisors to the area in an effort to combat poverty.

Through long-term observations, farmers have studied the behaviour of animals or birds, wind and cloud patterns, the shape of the moon, and other indigenous indicators to predict weather. A study by Makwara (2013) in Zimbabwe found that indigenous people have traditional ways of weather forecasting that helped them to plan their farming activities. Animal and bird behaviour, as well as the moon shape are common indigenous indicators used to predict weather by Bergville and uMsinga farmers. They agree that whenever a calf gets excited and starts jumping all over the place, it indicates pending rain. More people in Bergville utilize animal behaviour than in uMsinga. This may be due to lower livestock numbers in uMsinga because of deteriorating pastures in the area. In uMsinga, the sounds of birds such as insingizi/ingududu **(***Bucorvus leadbeateri*), ihlolamvula (*Tachymarptis melba)* and uthekwane (*Scopus umbretta*) also signify rain. In addition, when the ingududu **(***Bucorvus leadbeateri*) and inkonjane *(Cecropis cucullata)* birds are flying low, it is an indication of impending rain. Indigenous knowledge holders in uMsinga blame poachers and white people for killing these sacred birds (insingizi/ ingududu **(***Bucorvus leadbeateri*) and inkonjane *(Cecropis cucullata)*). They say the ancestors are not happy about this causing droughts to prevail as punishment. Though farmers in Bergville still appreciate bird behaviour, they believe that they no longer possess the same attributes of weather forecast as before, since one can hear the same bird sounds in winter as well. Moreover, the sounds have become obstructed by noise from radios or big machinery making them unreliable indicators.

Indigenous methods of weather predictions have tended to be ignored with the emergence of modern methods of weather forecasting (Risiro *et al.,* 2012). However Bergville and uMsinga farmers still consider them important and reliable sources of climate information. Wind patterns and direction are used to foretell upcoming drought, rainfall and temperatures. There were almost equal numbers of farmers from both areas who use wind to predict weather. Warm fast moving winds usually indicate a dry season with little or no rainfall. In Bergville, these warm winds blow towards the Indian Ocean. Strong, dense winds blowing from Durban/the Indian Ocean towards Swaziland (from east to west) called Mzansi, bring good rains which sometimes lead to floods. This is similar to the findings of Eeley *et al.,* (1999) who reported that westerly winds are unlikely to have had any major effect on patterns of rainfall in the more easterly regions of KwaZulu-Natal. According to Eeley *et al.,* (1999) westerly winds generally brings cold, dry conditions prevailed during the winter, with strong winds and cold air drainage off the Drakensberg mountains exacerbating the drying effect, particularly in the southern part of the province where the high mountains (altitude 1750 m) lie closer to the coast. The crocking of frogs indicates pending rain, with farmers believing that frogs crock to pull rain from the sky. Contrary to uMsinga, Bergville had few farmers who were able to observe cloud patterns in order to predict weather. They both agree that dark, heavy clouds bring rain. uMsinga farmers say white, scattered clouds observed early in the morning indicate high temperatures during the day. Trenberth, (2011) discovered that with high levels of pollution from industries heavy, dark cumulonimbus clouds are easily develop and they usually brings very higher intensity rainfall. The shape of the moon was also an essential indigenous weather indicator, more so in uMsinga than Bergville. When the moon is half shaped and facing downwards, IK holders believe it will rain within a few days. On the other hand when the moon is either full or half shaped and facing upwards, it will not rain. The reason given is that a half shaped moon facing upwards takes up water and reserves it to itself, then releases it when facing down. uMsinga farmers say that when the moon is facing Swaziland (i.e. westward), it brings more rain. Furthermore, farmers also use insects to predict weather though this is not a common practice in both areas. They say that whenever there is an outbreak of insects (ants and grasshoppers), it indicates pending drought, pests and disease outbreaks in the coming season.

Soil fertility degradation is one of the important constraints to food security in Sub-Saharan Africa (Verchot *et al.,* 2007). In South Africa, about 85% of the country is threatened by land degradation and desertification (Archer, 1994). A study by Dlamini *et al.,* (2011), discovered that water erosion was the main cause of land degradation reducing crop yields in Bergville. Soil and water conservation strategies and their sustainability are highly site-specific, so each village has its own set of methods applicable to that area. Rain water harvesting using buckets and tanks is a method used to trap water for household and garden use, with farmers in uMsinga doing this more often. Water shortages are not as severe in the wetter Bergville as in the drier uMsinga. Earth dams in both areas are also constructed downstream to store water, however these are usually small, lasting for short periods. Constructing a large dam in uMsinga would not be economical due to the reduced water supply in this area. Cattle manure is also added in both areas in an effort to improve soil fertility and preserve moisture, though uMsinga farmers use it more often. Manure aggregates soil particles, thereby preventing erosion and improving infiltration. Bergville farmers also use manure in combination with artificial fertilizers. Contour farming across the slope is also practised in both areas to preserve field soil from runoff and erosion, and enhance infiltration. This is often practised on steep slopes that are more prone to erosion. Farmers in both areas say they used to practise fallowing to allow for soil regeneration.

However, nowadays most farmland lies idle because farmers cannot afford the high input costs of farming. Mulching, ridges and furrows, green manuring and raised beds are some of the conservation strategies used in gardens but there is big debate on the sources of these methods. Most farmers in both areas believe these methods were adopted from science, while a few argue that they are their own inventions. The few who practise them are impressed with their ability to conserve both water and soil. Evidence from previous studies shows that irrigation system, tractors, certified seeds and inorganic fertilizer increase crop productivity (Verchot *et al.,* 2007). But this is variable due to differences in soil types, rainfall patterns, slope and other factors. Indigenous and scientific mechanisms are used separately or in combination in both Bergville and uMsinga.

Using the farmers' perception, soil fertility in Bergville significantly increased after using scientific methods such as zero tillage, terraces and mineral fertilizers. In contrast, more farmers in uMsinga believe that soil fertility improved after using indigenous methods such as manure addition and contour ploughing. Bergville farmers mostly use mineral fertilizers, zero tillage and mulches in gardens and small fields to improve soil fertility. They say the high costs of commercial fertilizer and huge initial investments of these strategies hinders them from using them on large fields. Cattle manure, which is also often insufficient and contour ploughing were utilized on large fields in Bergville, often resulting in low fertility gains. More yield gains were realised after use of indigenous methods (i.e. manure and contour ploughing) in uMsinga compared to scientific ways (i.e. fertilizer, zero tillage and terraces). This is because very few farmers in uMsinga are able to afford fertilizers, therefore they mostly rely on manure whereas in Bergville, farmers combine manure and mineral fertilizers to improve yields. Bergville farmers adopted soil fertility techniques from science without leaving their indigenous ways, while in uMsinga they are not keen to adopt scientific ways. In addition, indigenous strategies that were utilized to conserve soil and water in both areas were manure, contour ploughing and earth dams, while science strategies used were mineral fertilizers, zero tillage and tanks. Indigenous methods were prominent in both areas when compared to science because of their accessibility, simplicity and low requirement of skilled labour. Some of the scientific strategies such as the use of water tanks, discing, planters (where zero tillage is practised) and commercial fertilizers need high capital investments, which is a limiting factor to resource poor farmers especially in uMsinga where unemployment is high and agricultural production is low.

3.5 Conclusion

Communal farmers in Bergville and uMsinga practise both crop and livestock farming. However in uMsinga crop farming has been gradually declining due to unfavourable climatic and soil conditions. Livestock farming is also lower in uMsinga compared to Bergville. Farmers perceive that temperatures have been gradually increasing and rainfall declining and becoming more erratic over the years. Indigenous indicators used for predicting extreme weather events include animal, bird and insect behaviour; wind and cloud patterns as well as the shape of the moon. In both areas farmers utilize both indigenous and scientific strategies to preserve water and soil. Indigenous strategies used are rain water harvesting with buckets, manure addition, contour farming, fallowing, construction of earth dams and wells. Science-based strategies utilized are rain water harvesting with tanks, mulching, furrow/ridge planting, terraces using stones, cover crops and raised beds. The constraints that limit farmers to adopt scientific strategies are poor infrastructure, low technology, limited labour and lack of finances. However, they have managed to survive extreme events such as drought, floods, thunderstorms, diseases and pests using IKS. UMsinga has more farmers utilizing indigenous indicators to predict weather compared to Bergville. Reduced access to electricity in uMsinga compared to Bergville denies farmers modern methods of information. Communal farmers in both areas are capable of coping with climate variability to an extent, through strategies such as growing short season crops (vegetables), farm diversification, intercropping and crop rotation. Applying indigenous mechanism alone does not improve soil fertility, yield or conserve soil and water compared to where both science and indigenous mechanisms are combined. Though Bergville farmers still harvest enough food for consumption when rain is adequate, crop yield levels have generally declined over time. Scientific knowledge should be integrated with IKS to sustain agriculture production since agriculture is a source of survival to communal farmers. There is need to promote indigenous methods of coping with climate variability especially where modern methods are too expensive or difficult to implement. It can be concluded that communal farmers in both areas use time tested indigenous indicators for mitigating and adapting to climate variability. There is a need to understand effects of soil and water conservation strategies used by smallholder farmers in KZN on soil quality.

CHAPTER 4

EVALUATING THE EFFECT OF SOIL AND WATER CONSERVATION PRACTICES USED BY SMALLHOLDER FARMERS ON SOIL PHYSICO-CHEMICAL PROPERTIES

4.1 Introduction

Soil fertility depletion and degradation are major biophysical constraints to crop production in Sub-Sahara Africa (SSA) (Sanchez *et al*., 1997). Approximately 65% of agricultural land in SSA has been degraded through tillage and continuous cropping, with insufficient mineral and organic fertilizer application (Oldeman *et al*., 1991). According to Rockstrom *et al.,* (2009) at least a doubling of agricultural yields is required over the coming decades in economies where the population depends on smallholder rain-fed farming for their livelihoods. However increasing agricultural yields would be impossible, as most rural soils in SSA are inherently infertile (Rockstrom *et al.,* 2009). The type of tillage practised by farmers is a determinant of how soil and water would be conserved (Sanchez *et al*., 1997). Conventional tillage (using the mouldboard plough or tractor) is practised by the majority of communal farmers. Fowler & Rockstom, (2001) noted that most resource-poor farmers used hand-hoes or animal drawn ploughs for ploughing.

Communal farmers now appreciate the degradation caused by soil inversion, and utilise conservation strategies such as minimum tillage and the addition of readily available organic resources on their lands (Fowler & Rockstrom, 2001). In the study areas, as noted in Chapter 3, several techniques such as rain water harvesting with buckets and tanks, manure addition, contour farming, fallowing, mulching, furrow/ridge planting, terraces using stones, cover crops, raised beds, construction of earth dams and wells were used by communal farmers to conserve soil and water. Tillage techniques used in the study areas to conserve both soil and moisture were contour ploughing, minimum tillage, intercropping, zero tillage, ridges & furrows and fallowing. This is similar to the findings of Sanchez *et al.,* (1997) who reported that there are different conservation techniques used by communal farmers in SA ranging from contour ploughing, zero tillage, ridges & furrows and fallowing. It is however not clear whether some of these practices were adopted from science or are local inventions. Various studies have shown that reduction in soil cultivation, associated with minimum or zero tillage, can significantly change the distribution of plant-available nutrients within the surface soil (Shear & Moschler, 1969; Blevins *et al.,* 1977; Hodgson *et al.,* 1977; Doran, 1980; Ellis & Howse, 1980). In a study in Vaalharts, South Africa, Kutu, (2012) reported that zero tillage gave the highest maize grain yield of 2805 and 2776 kg ha^{-1} under supplementary irrigation and dryland conditions respectively. It also resulted in better conservation of soil nutrient reserves than conventional tillage (Kutu, 2012).

According to Kutu, (2012), the changing climate patterns coupled with increased cultivation of marginal lands exacerbates food insecurity. Farmers have limited resources to cope with these production constraints (Machethe *et al*., 2004; Mweta *et al*., 2007). As a result, they usually resort to farming methods that are familiar and have been practiced for centuries. Kihara *et al.,* (2011) assert that smallholder land productivity can be increased by optimizing locally available resources. Reduced tillage has been observed to result in better soil structure (Six *et al.,* 2000) and higher organic carbon compared to conventional tillage, especially in the top horizons (Madari *et al.* 2005; McCarty & Meisinger, 1997). Combined with crop residue mulch, reduced tillage also conserves available moisture important for crop growth. The objective of this study was therefore to evaluate the effects of different soil and water conservation practices used by smallholder farmers on soil physico-chemical properties in comparison with conventional tillage. The hypothesis was that conservation techniques would conserve more water and result in higher soil nutrient returns compared to conventional tillage.

4.2 Materials and Methods

4.2.1 Site selection and description

The study was conducted in Bergville and uMsinga both located in KwaZulu-Natal (KZN) Province (previously shown in Figure 3.1). These areas were chosen because of their contrasting climatic conditions, Bergville is humid (Nel, 2007) and uMsinga is semi-arid (Phipson, 2012). Several conservation techniques practiced by farmers namely zero tillage, ridges & furrows, raised beds, minimum tillage, contour ploughing, intercropping and fallowing were chosen and compared with conventional tillage. Minimum tillage is a soil conservation system with the goal of minimum soil manipulation necessary for successful crop production (Paul *et al.,* 2013). Communal farmers in both Bergville and uMsinga were using a disk ripper, provided by FSG, to minimally till the soil. According to Harris (1999), fallowing is leaving the land untilled for a while to allow it enough time to recuperate so as to preserve soil nutrients and maintain natural productivity. Farmers in Bergville and uMsinga also allow their cattle access to feed on crop residues left on their fields, and in turn get manure dropped onto their fields. The ridge/furrow that was practiced by communal farmers was mainly for soil water conservation in small fields and gardens. Farmers made ridges with soil, grass and plant residues and planted in the furrows. Vegetable such as cabbage, spinach and tomatoes were planted in the furrows however in the small fields potatoes were mostly planted in the ridges and maize on the furrows. Intercropping is planting a tall crop with a short crop and was employed mostly to conserve water and soil in Bergville and uMsinga. Contour ploughing was practised on steep slopes in order to conserve both water and soil though they are similar with conventional in terms of equipment used (mouldboard plough) the major difference is that contour ridges are set up across the slope. In zero tillage there was no ploughing, and weeds were controlled through application of herbicides. According to Six *et al.,* (2004) conventional tillage completely inverts the soil (e.g. mouldboard ploughing), while zero tillage or no-till creates a negligible amount of soil disturbance (a narrow slot is opened for seed insertion with no-till planters). Farmers used either mould plough or tractors in conventional tillage and planters under zero tillage system in both Bergville and uMsinga.

Zero and conventional tillage were practiced in both gardens and fields. Raised beds and ridges/furrows were practiced in gardens while fallowing, intercropping, minimum tillage and contour ploughing were used in the fields. Although both areas have diverse soils, ranging from low to high agricultural potential, Msinga is mostly dominated by low production soils due to high susceptibility to erosion because they are sandy, shallow, with poor drainage (Institute of Natural Resources, 2007). uMsinga is dominated by Mispah, Glenrosa and Milkwood which are all shallow soils (Nyiraruhimbi, 2012). Bergville soils are mostly Hutton, Pinedene, Clovely and Griffin soil forms which have good agricultural production potential (Phipson, 2012).

4.2.2.1 Sampling Procedure.

The 8 villages from each study areas utilised during the baseline survey (Chapter 3) were chosen giving 16 villages all together. Different conservation techniques were practised in the villages which guided our sampling procedure. In each village one farm and one garden practising conservation tillage were sampled and one farm that practising conventional tillage was also sampled thus making 3 sampling sites. Sampling was done at 0-20, 20-40 and 40-60 cm depths making 9 samples in each village. There were 72 samples in each study area giving 144 samples when combined. GPS points were taken immediately after sampling. Clods for aggregate stability and cores for bulk density were sampled at 0-20 cm depth only. Collected soil samples was spread out to air dry. Air-dry soil was gently crushed with a mortar to pass a 2 mm sieve prior to analysis. To measure bulk density, a hand operated core sampler was utilized. The soil surface was smoothly prepared, by removing organic material and grass where sampling took place. A core sampler was driven far enough into the soil to fill the inner cylinder but not too much as to compress the soil (Blake, 1965). The sampler was carefully removed so as to preserve the sample. The core sample was trimmed with each end of the cylinder, then pushed into a well labelled plastic bag before taking it to the laboratory while ensuring minimum disturbance.

4.2.2 Laboratory Analyses

4. 2.2.1 pH and electrical conductivity (EC)

Air dried soil samples, (10 g), were weighed and transferred to 50 mL beakers. Both distilled water and 1M KCI were used to determine pH at a ratio of 1: 2.5, with 25 mL of either distilled water or KCI were added to the beaker (Diez *et al.,* 2004). Samples were allowed to stand for 30 minutes with occasional stirring using glass rods. An electrode pH meter (PHM 210) was used to measure the pH of the supernatant liquid. The samples with water added were then also used to measure electrical conductivity (in d Sm^{-1}) using an EC meter (CDM 210).

4.2.2.2 Total nitrogen and carbon.

Total N and C were analyzed using LECO TruMac CNS/NS Carbon/Nitrogen/Sulfur Determinator (Leco Corporation, 2012). Air dried soil samples were passed through a 0.5 mm sieve size, then a 0.2 g sample was then measured and put into the LECO for analysis of C and C. The procedure is based on dry combustion of air dried samples in crucibles, subjected to a 1450 ^{0}C furnace temperature for about 6 minutes. The C: N ratios of the soils were also calculated.

4.2.2.3 Exchangeable acidity

After air drying soil samples, 10 g was accurately weighed and transferred into a 100 mL plastic centrifuge tube (Lourenzi *et al.,* 2011). Then 50 mL of 1M KCI was added into the centrifuge tube before sealing and shaking for 4 minutes. It was then centrifuged for 2 minutes at 400 rpm and the solution was filtered through a Whatman No 41 filter paper into the glass bottle. A 25 mL aliquot was extracted into a 100 mL conical flask. Another 25 mL of 1M KCI only served as a blank, 5 drops of phenolphthalein indicator was added to each sample then titrated with

0.01M NaOH. The blank was titrated first following steps by Ndayegamiye and Cote (1989). The solution was titrated until it remained pink for at least 30 seconds, then exchangeable acidity was calculated in cmol$_c$/kg Edwards and Duncan (2009). The formulae used in calculating exchangeable acidity was as follows by Smith and Hughes, (2002):

$$\text{Exchangeable acidity (mg/L)} = \frac{VNaOH*CNaoH}{VH+}$$

$$\text{Exchangeable Acidity (cmol}_c\text{/kg)} = \text{mg/L} * \frac{50\ mL}{1000} * \frac{1000}{5g} * 1 * 1000.$$

Where 50 ml is the solution and 5 g is the soil used.

4.2.2.4 Exchangeable bases

Air dry soil (4.0 g) was weighed into a 50 mL centrifuge tube. A 40 mL Mehlich 3 extracting solution (0.2 M CH_3COOOH + 0.25 M NH_4N0_3 + 0.015 M NH_4F + 0.013 M HNO_3 + 0.001 M EDTA) with glacial 17 M acetic acid and 15 M nitric acid were added to each tube and placed on reciprocating shaker for 5 minutes at 200 oscillation per minute. The samples were then centrifuged at 8 300 rpm for 5 minutes and filtered through Whatman No 1 filter paper, before analysing by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), 5300 DV, for Ca, Mg, K and Na using a wavelength of 550 nm (Wolf and Beegle, 2009).

4.2.2.5 Available phosphorus

Finely grounded air-dried soil (5 g) was wieghed and put into a centrifuge tube of 100 cm^3 capacity with stopper. Then 50 cm^3 of AMBIC-2 extraction solution (0.25 mol/dm^3, NH_4HCO_3, 0.01 mol/dm$_3$ Na_2 EDTA, 0.01 mol/dm^3 NH_4F and Superfloc) was added to the soil, the solution had a temperature of 20 ± 2 ^{o}C (Van der Merwe, 1980). The centrifuge tube was then swirled gently to expel air bubbles, then allowed to stand for 20 minutes, swirled again and sealed with a Cu and Zn free stopper. It was then shaken horizontally on a reciprocating shaker for 30 minutes at 180 oscillations per minute at an ambient temperature of 20 ± 2 ^{o}C. Centrifuge tubes were carefully removed from the shaker, allowed to stand for 5 minutes and stoppers were removed. The solution was filtered through Whatman No 41 filter paper. A 25 cm^3 aliquot of this solution was transferred into a 50 cm^3 volumetric flask. Concentrated HCI of 2.5 cm^3 was added and the flask was swirled gently. Contents were left overnight to allow precipitation of organic material (Thompson and Purves, 1981). De-ionized water was then used to make up to the volume, before shaking and filtering the solution through Whatman No 41 paper into a glass bottle. The colour reagent was prepared using two solutions. First solution was prepared by putting 2 g antimony potassium tartrate in a 2 litre pyrex volumetric flask, 300 mL of concentrated $H2SO_4$ and about 800 mL distilled water was added. The solution was allowed to cool overnight before adding 15 g ammonium molybdate which was dissolved in 600 mL distilled water. The second solution was prepared by diluting 150 Ml of first solution to a 1 litre with a solution containing 1 g gelatin/litre then 1 g of ascorbic acid was added and mixed. Standards were prepared from P stocks with AMBIC solution and HCI. Available phosphorus was determined using a spectrophotometer by reading absorbance at 670 nm. Calculations get P in the soil were used following Hunter, (1974) methods.

$$\text{P in soil (mg/dm}^3\text{)} = \frac{a*25}{2.5}$$

Where a= mg/dm^3 in the extract, 2.5 was the volume of HCI and 25 aliquot of the solution.

4.2.2.6 Soil Organic Carbon

Soil organic carbon was determined using the Walkey-Black method (Reeuwijk, 2002). Finely ground soil (1.0 g) was weighed into 500 mL Erlenmeyer flask and 10 mL of 0.167 M K_2CrO_7 solution was added. The flask was gently swirled, then 20 mL of H_2SO_4 was added rapidly with continuous swirling and it was allowed to cool for 30 minutes. De-ionized water (150 mL), 10 mL of concentrated ortho-phosphoric acid and 1 mL of barium diphenylamine sulphonate indicator were also added. The dichromate was back titrated against 0.5 M ferrous ammonium sulphate solution. At the end point the colour changed sharply to green (Reeuwijk, 2002). The formula by Reeuwijk, (2002) was used to calculate organic C.

$$C_{HCI} = \frac{VNaOH*CNaoH}{VHCI}$$

$$y\ (\text{mL}) = \frac{VFAS*CFAS}{VK2CrO7*6}$$

$$\text{Organic C (\%)} = X*\frac{12}{4}*1.33*\frac{100}{soil\ mass\ (mg)}$$

Where 1.33 is a correction factor

4.2.2.7 Bulk Density

The whole soil core was placed in a weighing boat and weighed. The weight of the wet soil plus boat plus plastic bag was recorded as W_l, while weights of the boat and plastic bag were recorded as W_2 and W_3, respectively. W_2 and W_3 were measured before sampling and after drying according to Blake (1965). The samples were then dried in an oven at 105 °C. The time required to dry the sample varied with the amount of soil present. For cores, 7.62 cm (diameter) x 7.62 cm (long), we used 72 hours to dry; for smaller cores 48 hours was required (Blake, 1965). The combined weight of the oven dry sample, boat and plastic bag were recorded as W_4. The wet weight (W_l) was used to calculate the moisture content at time of sampling.

Bulk density (kg/m^3) = W_4-W_2-W_3 / volume of cylinder

4.2.2.8 Aggregate Stability

The Emerson's stability test was used for analyzing aggregate stability through mean weight diameter. Clods were sampled using a pick at the 0-20 cm depth only. The clods were then air dried at atmospheric temperature. Clods (3 to 5 mm in size) were oven-dried at 40 °C for 24 hours, in order to prevent contrasts in humidity and to make the sample conditions uniform (Grievel, 1980). Aggregates of 3-5 mm diameter were weighed, with initial weight in the range of 5-10 g. Deionized water (50 ml) was poured in a 100 ml beaker and the aggregates were placed inside. Slaking was observed visually for 10 minutes and then excess water from the beaker was removed using a pipette. Aggregates were transferred into a 50 µm sieve which was immersed into ethanol. Henin *et al.,* (1958) states that the goal of this part of the procedure is to describe the results of the disaggregation while avoiding any further disaggregation. Soil fraction greater than 50 µm was passed through a set of 6 sieves (2000, 1000, 500, 200, 50 and pan). The weight of the fraction smaller than 50 µm was inferred by difference with initial weight (Henin *et al.,* 1958). Mean weight diameter (MWD) was then calculated in mm units, with values ranging between 0.025 – 3.5 mm. Calculation of MWD was based on a formula derived from Henin *et al.,* (1958) and improved by Haynes, (1993).

$$\text{MWD} = \sum(d * w)$$

d – Mean diameter between size fractions w – Proportion by weight of size fraction

4.2.2.9 Particle size distribution.

Particle-size analysis was done using the sieve and double pipette method (Walter *et al*., 1978). Calgon solution was prepared with 35.7 g sodium hexamataphosphate and 7.9 sodium carbonate in de-ionized water and was made-up to 1 L. Soil (50 g) was weighed into a 100 mL beaker, then 50 mL of calgon was added and samples were treated for 3 minutes with ultrasonic probe at maximum output. The probe tip was immersed about 13 mm into the liquid but not too close to the bottom of the beaker to avoid breakage. Dispersed samples were washed through the 0.053 mm sieve into 1 L measuring cylinder with distilled water. Soil fraction coarser than 0.053 mm was transferred into 250 mL beaker and dried in an oven at 105 °C overnight. This was the sand fraction, and it was transferred to a nest of sieves. Sieves were arranged in apertures of 0.500 mm, 0.250 mm, 0.106 mm and pan, and these were shaken for 5 minutes. The mass of empty sieves was firstly recorded accurately after which it was again recorded with the soil fraction. The clay and silt fraction were analyzed in the sedimentation column. Different settling times were used guided by the temperature of sedimentation. After the appropriate settling time, fine silt was sampled at 100 mm and clay was sampled at 75 mm below the surface. After plunging the sedimentation column, 20 ml of the soil suspension was pipetted using a double pipette into a pre-weighed 50 mL beaker and placed in an oven at 105 °C overnight. The following day, beakers were removed from the oven, allowed to cool in a desiccator and re-weighed. Proportions of sand, silt and clay were calculated and expressed as percentages of the total then used to determine soil textural class using the textural triangle.

4.2.2.10 Soil Moisture Content.

Freshly sampled field-moist soil (5.0 g) was weighed and dried overnight at 105 °C, after which the oven-dry sample was weighed to determine its dry mass. (Reeuwijk, 2002). Moisture content was calculated using the formula by Reeuwijk, (2002):

$$\text{Moisture (wt\%)} = \frac{wet\ soil\ weight - oven\ dry\ soil\ weight}{oven\ dry\ soil\ weight}(100)$$

Furthermore the moisture correction factor was calculated using the formula:

$$\text{Moisture correction factor} = \frac{100 + \%\,Moisture}{100}$$

4.2.3 Statistical Analyses

An analysis of variance (ANOVA) test was done to determine the effect of conservation technique on soil physio-chemical parameters at different soil depths. The treatment factors were district, conservation technique and soil depth. The Duncan's LSD test was used as a post-hoc test for multiple comparison to compare treatment means. A correlation analysis was also done using Pearson's product moment correlation coefficient (r value; $\alpha = 0.05$) to evaluate relationships between the different soil variables. All tests were performed with GenStat 14.1 for Windows software (VSN international, 2011).

4.3 Results

4.3.1 Effect of different conservation techniques on pH in Bergville and uMsinga in comparison with conventional tillage.

Figure 4.1 shows that in Bergville furrow/ridge planting had highest cumulative pH for all depth levels while intercropping had the lowest pH ($p < 0.001$, Appendix B.1). Fallowing and zero tillage had the highest cumulative pH in uMsinga whereas contour ploughing had the lowest cumulative pH. Conventional tillage itself had lower cumulative pH than furrow/ridge at Bergville, while it had amongst the highest pH levels at uMsinga. In all the different techniques uMsinga had higher pH than Bergville at all depth levels, but there were no significant notable pH trends with depth in both areas.

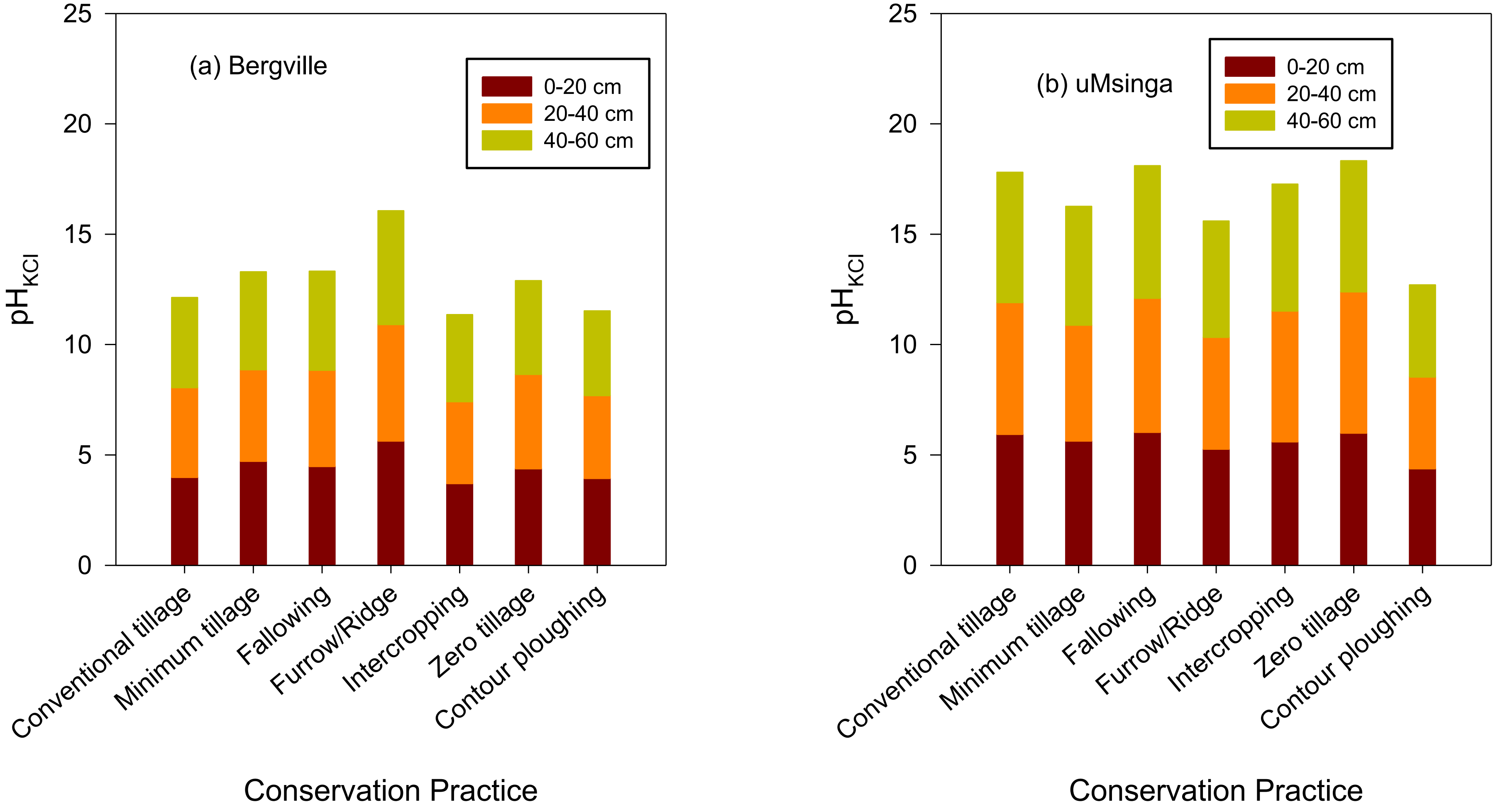

Figure 4. 1: Effect of conservation technique on pH in Bergville (a) and uMsinga (b) in comparison with conventional tillage

4.3.2. Effect of different conservation techniques on exchangeable aluminium in Bergville and uMsinga in comparison with conventional tillage.

Figure 4.2 shows that the cumulative exchangeable aluminium in Bergville was highest in contour ploughing followed by intercropping and conventional tillage, while the lowest was under minimum tillage followed by ridge/furrow planting and fallow farming ($p < 0.001$, Appendix C.1). A closer look at the depth showed than the 20-40 cm depth contributed the highest amount of exchangeable aluminium in most of the treatments at Bergville ($p = 0.008$, Appendix C.1). In uMsinga, the highest cumulative exchangeable aluminium was under furrow/ridge planting, followed by contour ploughing and conventional ploughing, while fallowing, minimum and zero tillage had the lowest total exchangeable aluminium compared to the other techniques. The highest individual exchangeable aluminium in uMsinga was under contour ploughing, furrow/ridge planting and conventional tillage all at 20-40 cm depth (Figure 4.2).

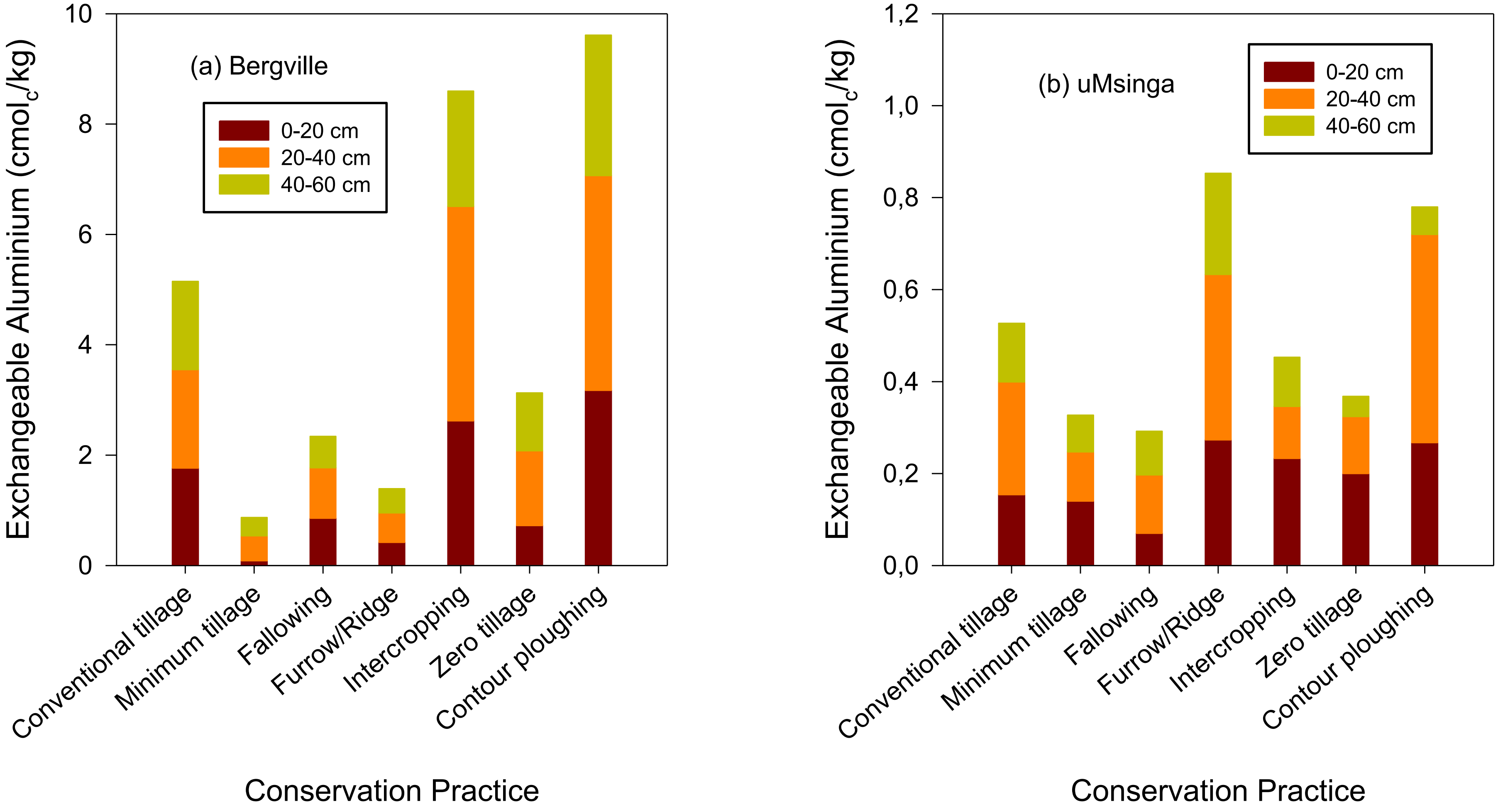

Figure 4. 2: Effect of conservation technique exchangeable aluminium in Bergville (a) and uMsinga (b) in comparison with conventional tillage.

4.3.3 Effect of different conservation techniques on exchangeable bases in Bergville and uMsinga in comparison with conventional tillage.

Figure 4.3 shows that the highest cumulative amounts of exchangeable bases across all depths were recorded under minimum tillage followed by zero tillage, fallowing then conventional tillage in Bergville, whereas in uMsinga, bases were highest under furrow/ridge, intercropping, contour then conventional tillage ($p < 0.001$, Appendix D.1). There were no significant notable trends of bases with depth however in both areas. Bergville generally had higher cumulative amounts of bases in most of the techniques serve for furrow/ridge, intercropping and contour ploughing.

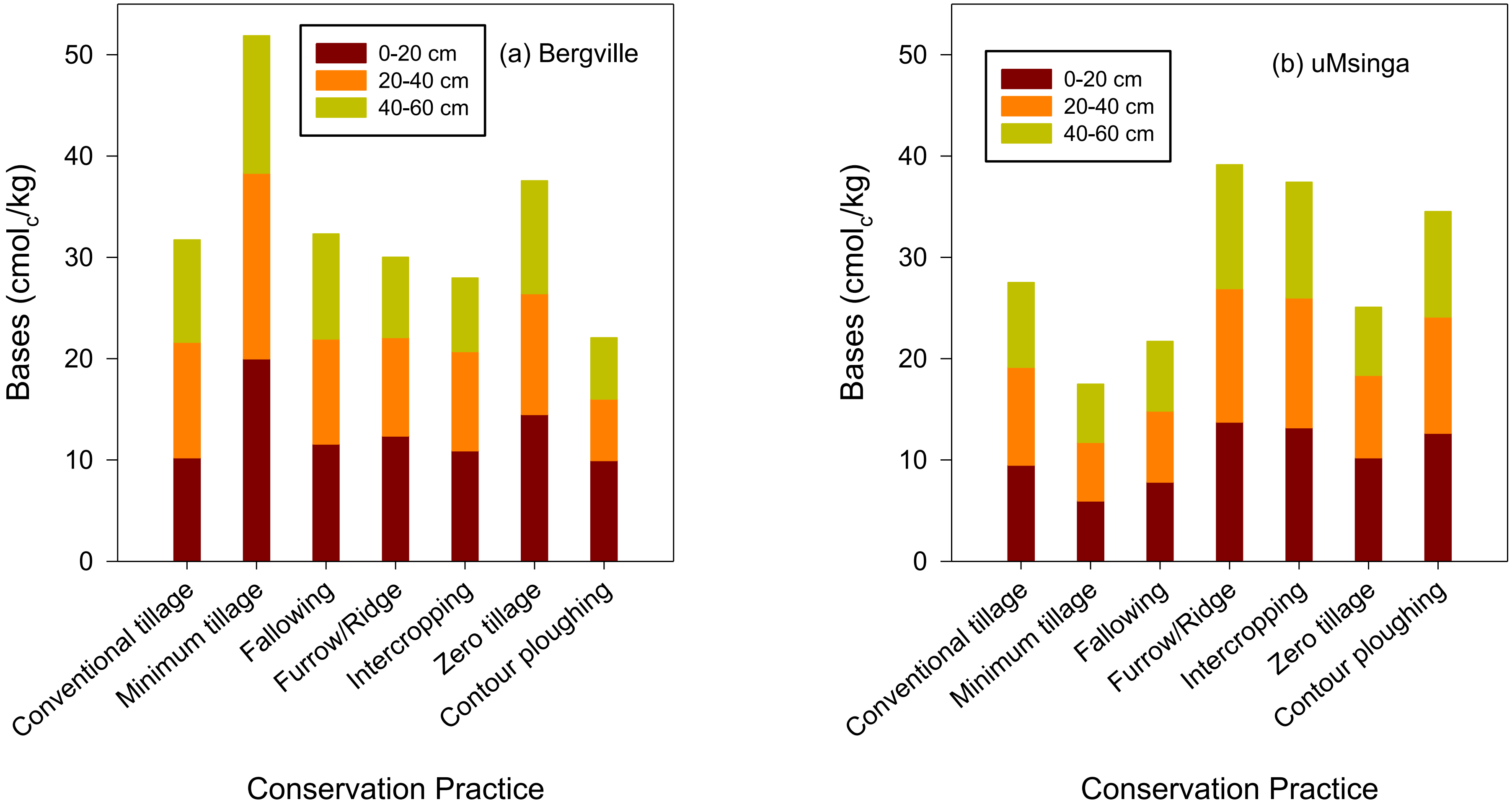

Figure 4. 3: Effect of conservation technique on bases in Bergville (a) and uMsinga (b) in comparison with conventional tillage.

4.3.4 Effect of different conservation techniques on available P in Bergville and uMsinga in comparison with conventional tillage.

Available P in Bergville was highest under zero tillage followed by furrow/ridge planting, minimum then conventional tillage, while the least available P was in contour ploughing and intercropping (Figure 4.4). In uMsinga the least available P was under contour ploughing, minimum then conventional tillage, while the highest available P was under zero tillage and intercropping ($p < 0.001$, Appendix E.1). Most of the available P was concentrated in the top 20 cm of many of the techniques, particularly at Bergville ($p < 0.001$, Appendix E.1), with Bergville generally having higher P levels than uMsinga for most techniques.

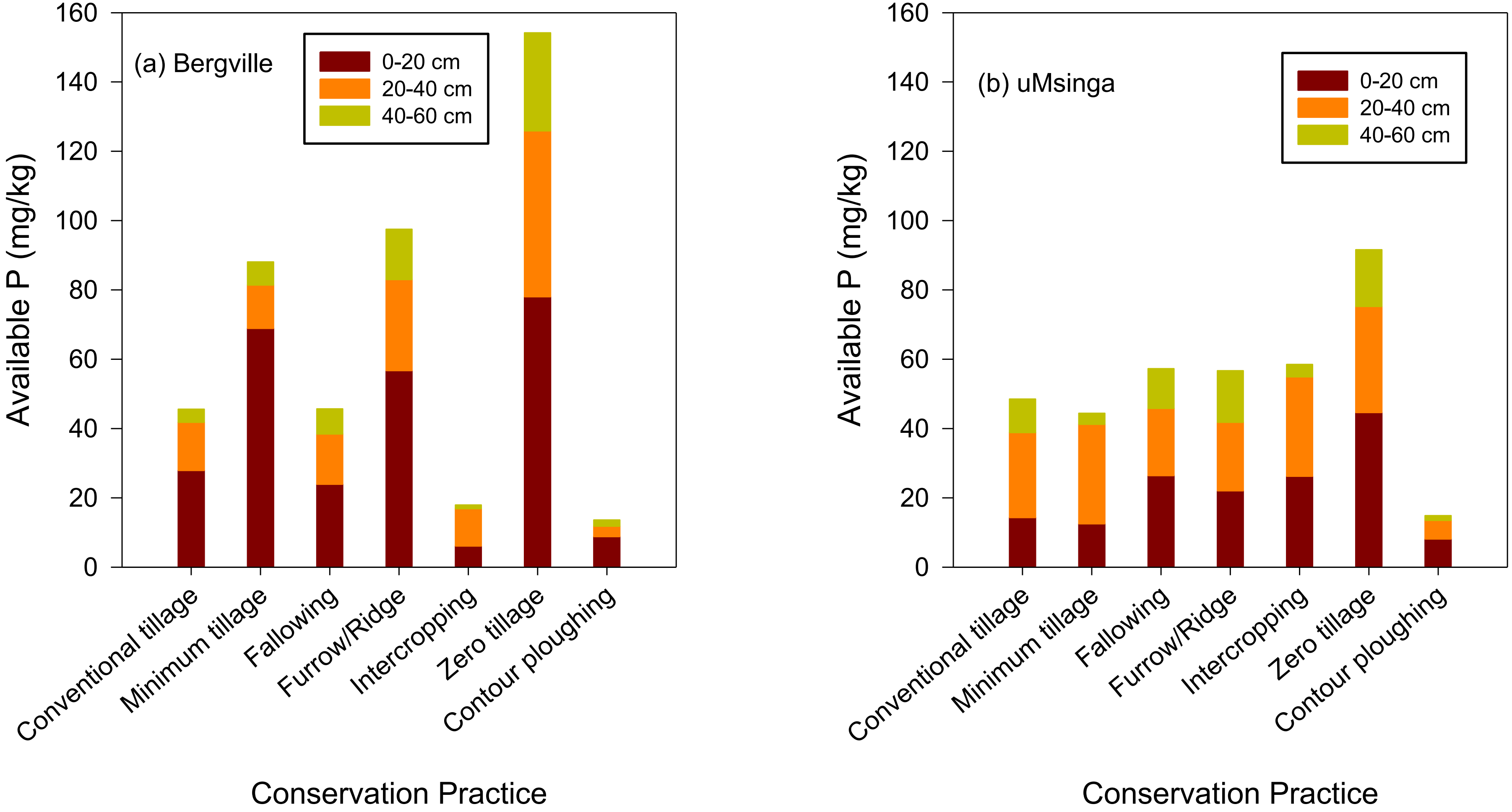

Figure 4. 4: Effect of conservation technique on available P in Bergville (a) and uMsinga (b) in comparison with conventional tillage.

4.3.5 Effect of different conservation techniques on Organic C in Bergville and uMsinga in comparison with conventional tillage.

Organic C progressively decreased with depth in all the techniques in both areas ($p < 0.001$, Appendix F.1) as evidenced by the very high C in the top 0-20 cm depth (Figure 4.5). In Bergville, the order of cumulative organic C levels was zero tillage > contour ploughing > intercropping > minimum tillage > conventional tillage, whereas in uMsinga it was furrow/ridge > intercropping > minimum tillage > contour ploughing > conventional tillage ($p < 0.001$, Appendix F.1). The least cumulative organic C in Bergville was under fallowing and ridge/furrow planting while in uMsinga it was under fallowing and zero tillage.

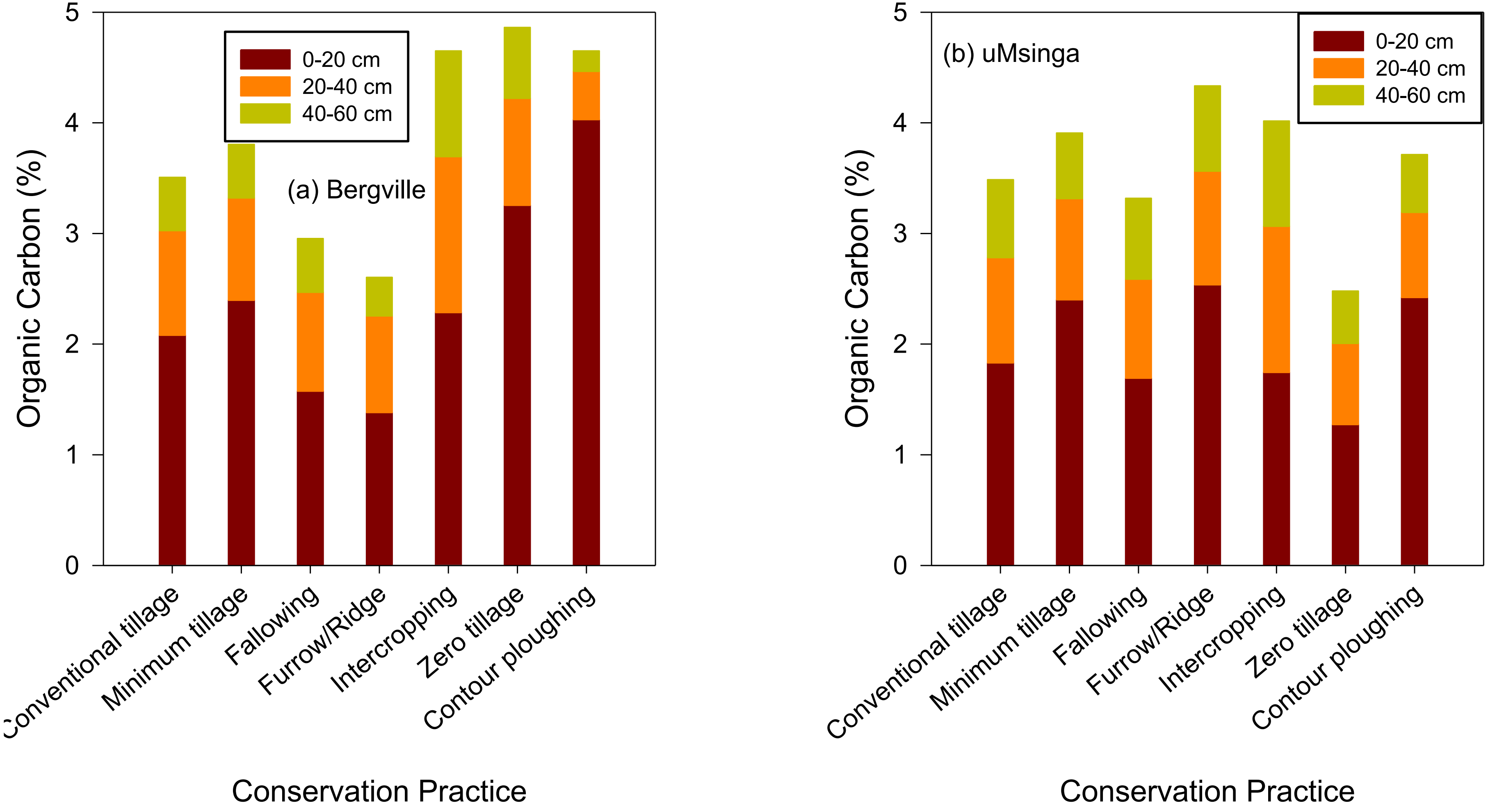

Figure 4. 5: Effect of conservation technique on Organic carbon in Bergville (a) and uMsinga (b) in comparison with conventional tillage.

4.3.6. Effect of different conservation techniques on aggregate stability in Bergville and uMsinga in comparison with conventional tillage.

Mean weight diameter (MWD) in Bergville was highest under contour ploughing, zero, conventional tillage then fallowing ($p < 0.001$, Appendix G.1), with furrow/ridge planting and minimum tillage having the least MWD (Figure 4.6). In uMsinga MWD furrow/ridge planting, contour ploughing and conventional tillage had the highest while fallowing and intercropping had the least MWDs. Bergville had higher MWDs than uMsinga for all techniques serve for minimum tillage.

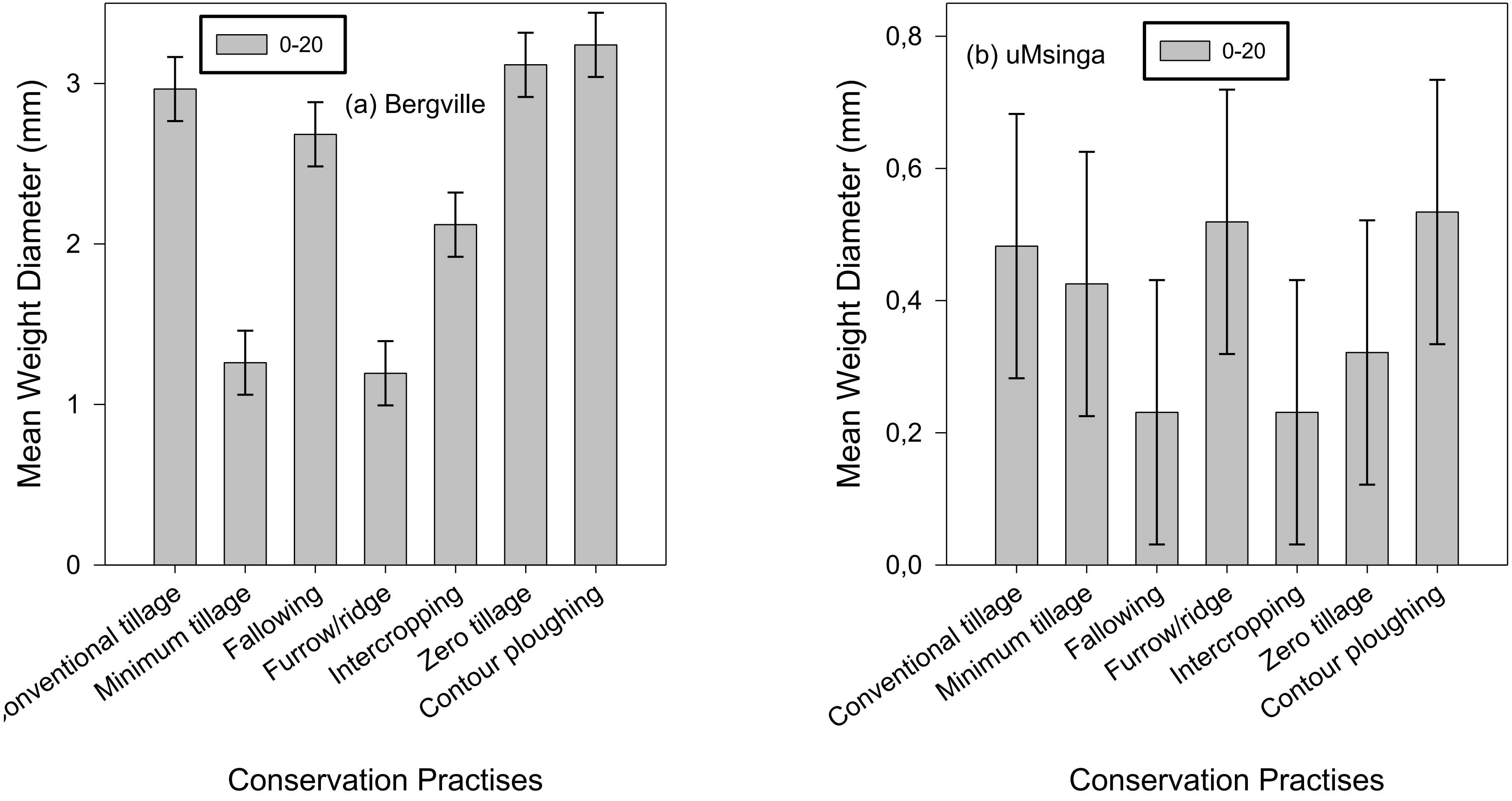

Figure 4. 6: Effect of conservation technique on aggregate stability in Bergville (a) and uMsinga (b) in comparison with conventional tillage.

4.3. 7 Effect of different conservation techniques on bulk density in Bergville and uMsinga in comparison with conventional tillage.

Figure 4.7 shows that uMsinga had higher bulk density than Bergville in most of the techniques serve for contour ploughing. Though no clear trends in bulk density were observed between the techniques at Bergville, furrow/ridge and contour ploughing had significantly lower densities at uMsinga ($p < 0.001$, Appendix H.1).

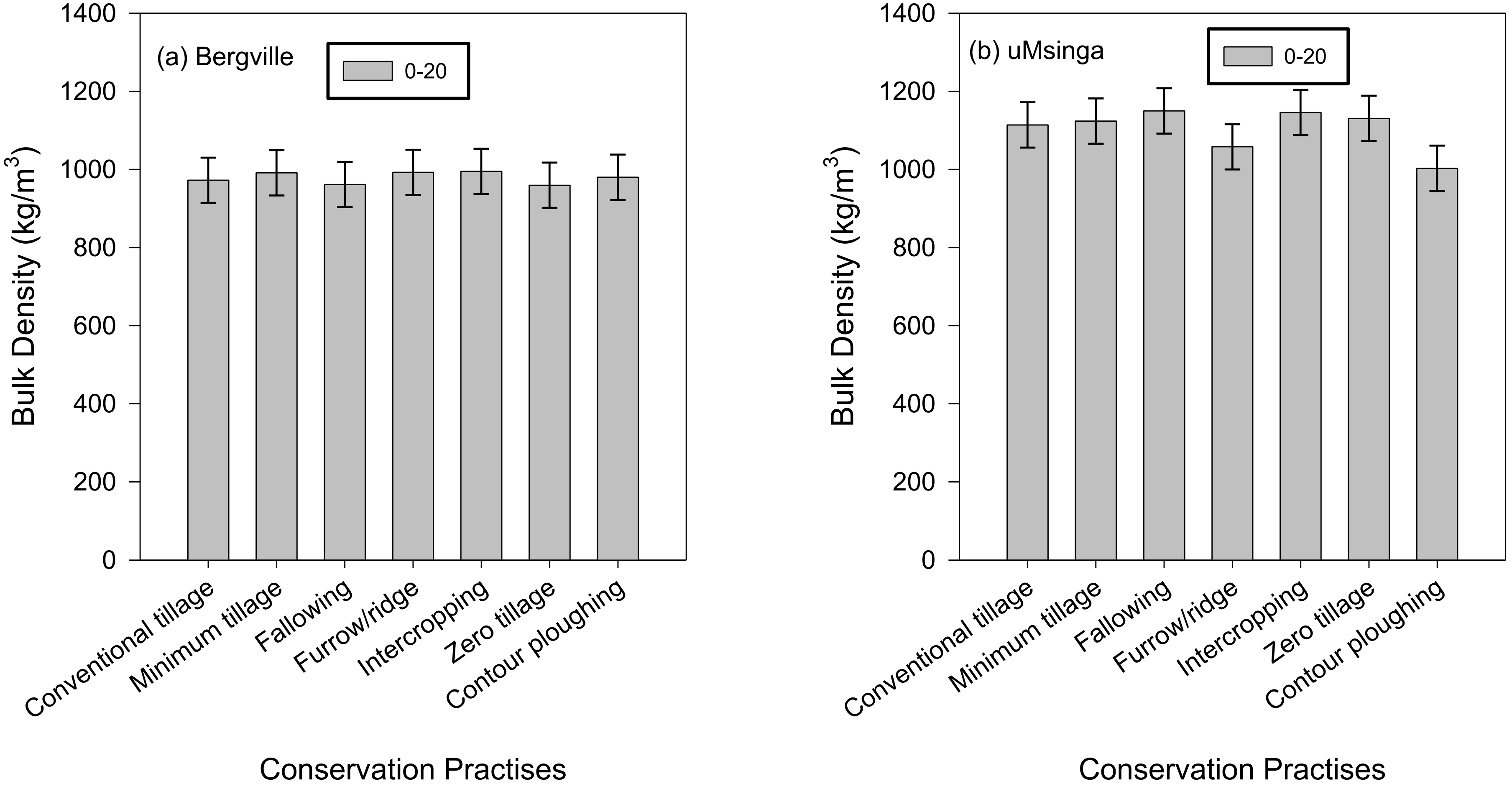

Figure 4. 7: Effect of conservation technique on bulk density in Bergville (a) and uMsinga (b) in comparison with conventional tillage.

4.3.8 Variations in particle size fractions in the different conservation techniques

Results for particle size analysis are shown for the top 0-20 cm only. Figure 4.8 shows variation of the sand fraction in Bergville and uMsinga under different conservation techniques. The sequence of sand fraction percentage in Bergville from the highest to lowest was: furrow/ridge > minimum tillage > fallowing ($p < 0.001$, Appendix I.1i). The other techniques namely conventional and zero tillage, intercropping and contour ploughing did not differ in sand amounts from fallowing. In uMsinga the practices with the highest sand fraction were contour ploughing and zero tillage, and these were significantly higher than minimum tillage, fallowing and ridge/furrow ($p < 0.001$, Appendix I.1i). uMsinga had significantly higher sand amount than Bergville for all the practices ($p < 0.001$, Appendix I.1i).

In Bergville, the practices with the highest silt fractions were zero tillage, intercropping and conventional ploughing, while those with the lowest silt were fallowing, contour and furrow/ridge (Figure 4.9). Zero tillage, intercropping, conventional and minimum tillage had significantly higher silt amounts than the ridge/furrow treatment ($p < 0.001$, Appendix I.1ii). There were no significant differences in silt amounts between the conservation practices at uMsinga (Figure 4.9). However, Bergville generally had higher silt amount than uMsinga in most of the practices (Figure 4.9).

Bergville had consistently higher clay amounts in all the techniques than uMsinga (Figure 4.10). Contour ploughing had highest while minimum tillage had the lowest, and all the other techniques did not significantly differ in clay fraction at Bergville ($p < 0.001$, Appendix I.1). No notable differences in clay amounts were recorded between the techniques at uMsinga however.

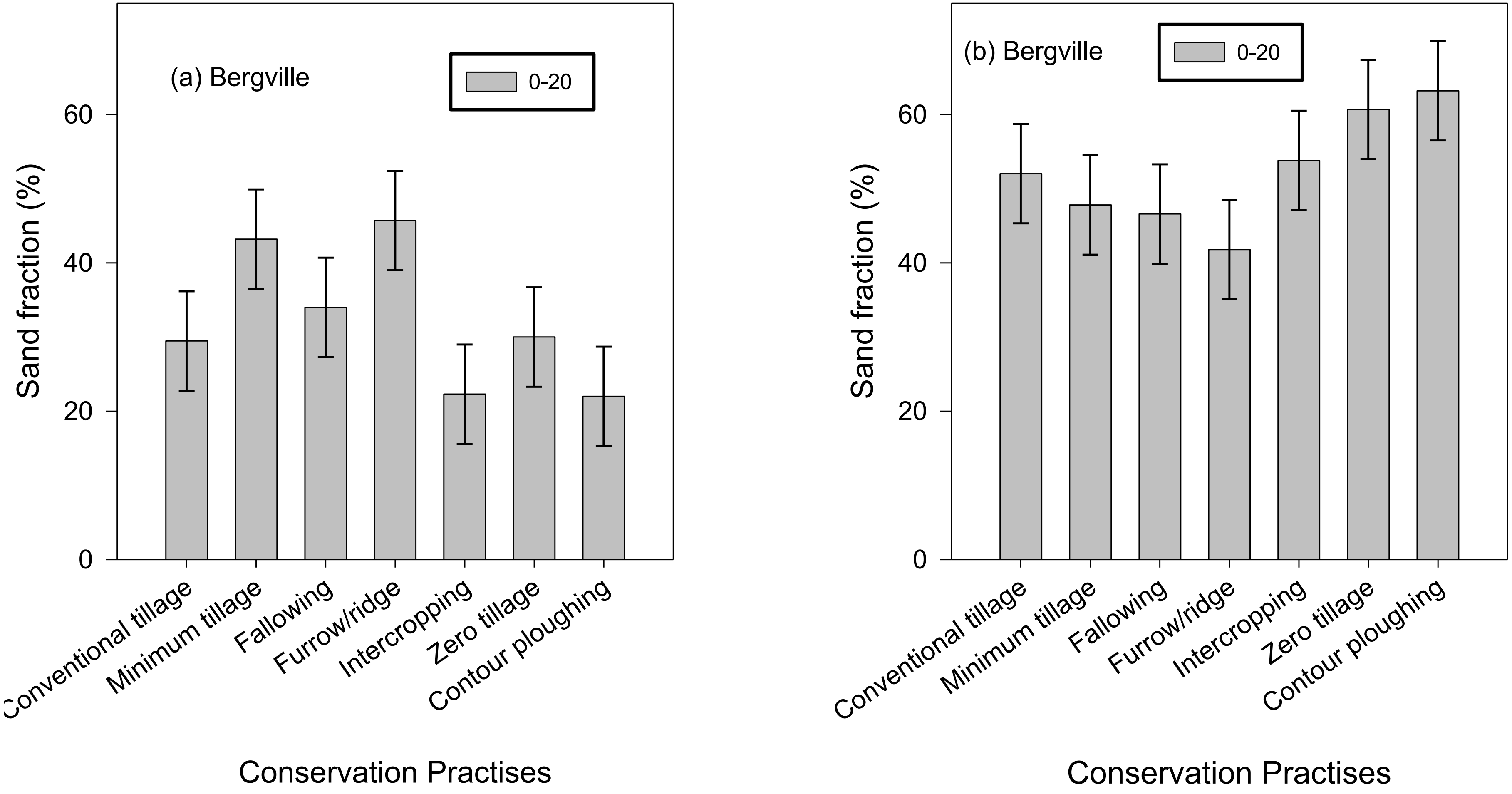

Figure 4. 8: Comparison of sand fraction in different techniques at Bergville and uMsinga.

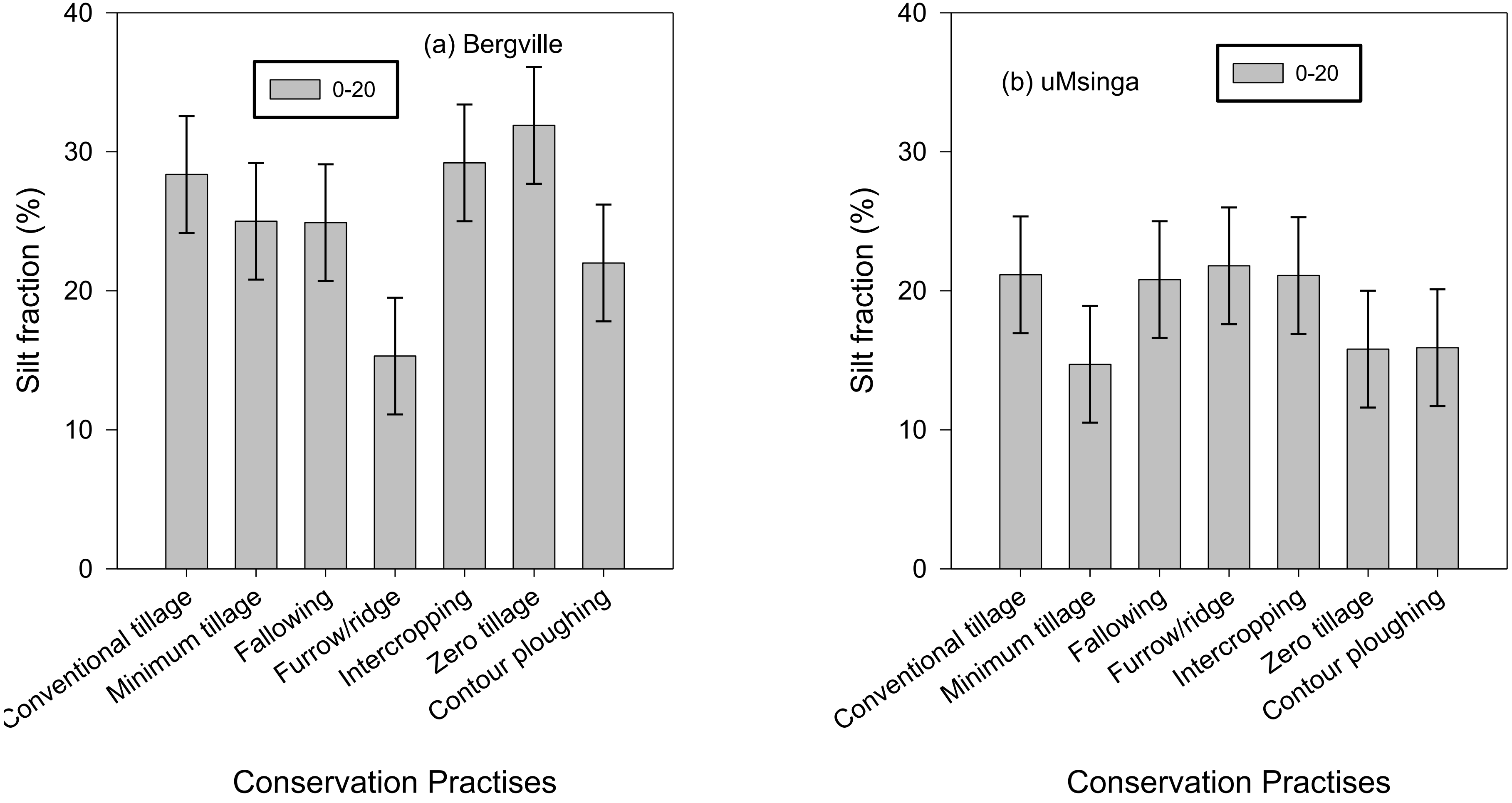

Figure 4. 9: Comparison of silt fraction in different techniques in Bergville and uMsinga.

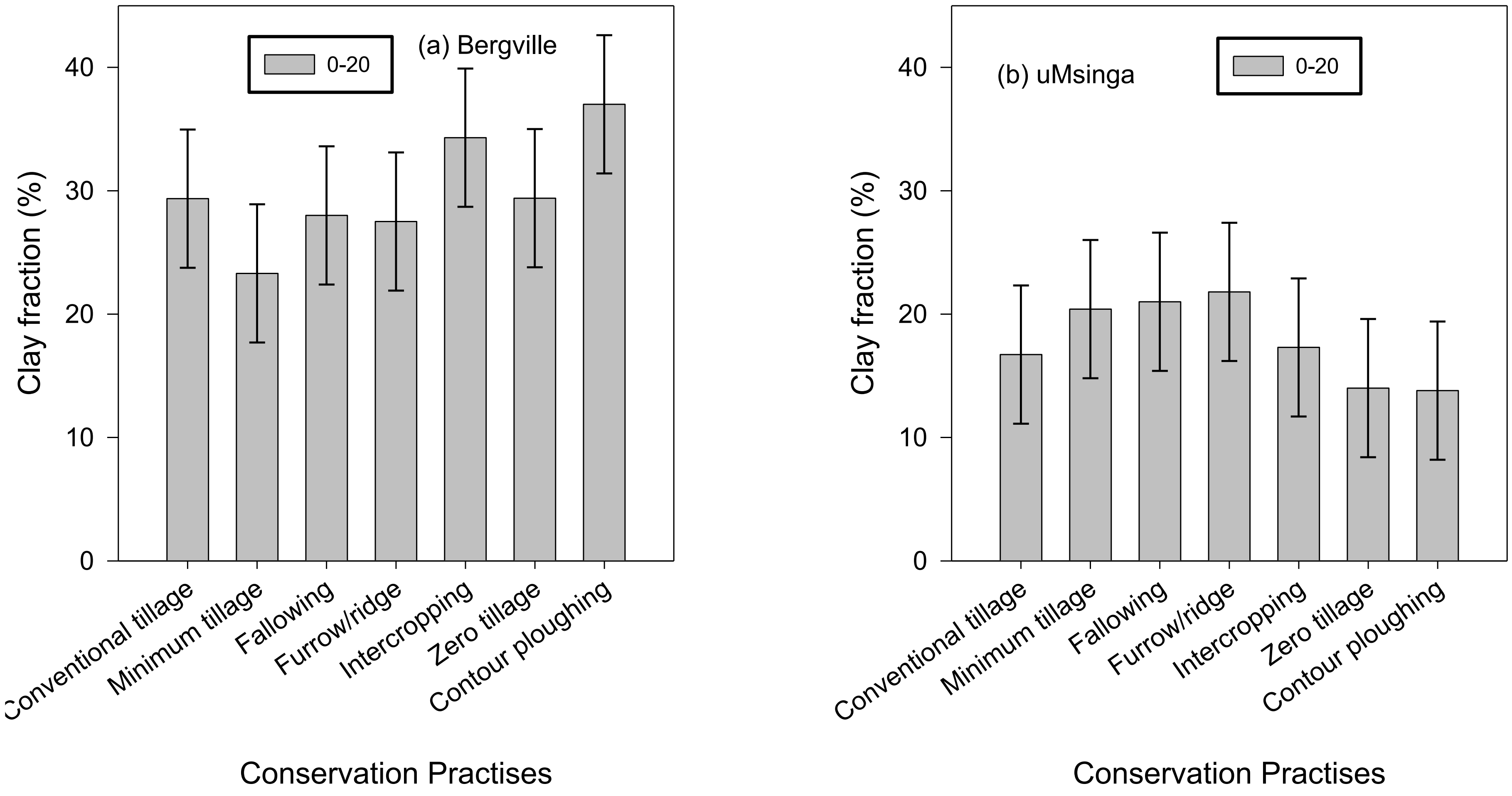

Figure 4. 10: Comparison of clay fraction in different techniques in Bergville and uMsinga.

4.3.5. Effect of particle size fractions on soil properties of the different techniques

Table 4.1 shows the correlations between textural fractions and the different soil variables in Bergville. The clay fraction had a significant effect on only three of the variables at Bergville, as it was positively correlated with available P (r = 0.4) and Mg (r = 0.3) but negatively correlated with pH (r = -0.4; Table 4.1). The opposite was true for the sand fraction however since it negatively correlated with P (r = -0.5) and Mg (r = -0.3) but was positively correlated with pH (r = 0.4). The silt fraction had a positive correlation with soil moisture only (r = 0.3) at Bergville.

Looking at other correlations between the soil variables at Bergville as shown in Appendix J.1, soil pH was positively correlated with Ca (r = 0.4), Mg (r =0.4) , Na (r = 0.3); and negatively correlated with Al (r = - 0.8). The conservation practice itself had a significant impact only on Al (r = 0.4), EC (r = 0.3), pH (r =-0.4), Mg (r =-0.3) and Ca (r =-0.2). Soil water only positively influenced OC (r =0.3), but was negatively correlated with Na (r =-0.5) at Bergville (Appendix J.1).

Table 4. 1: Correlation between textural fractions and soil properties at Bergville.

Soil properties	Clay	Silt	Sand
pH$_{KCl}$	-0.4*	0.03	0.4*
PH*w*	-0.3*	0.0	0.3*
EC (dS/m)	-0.1	-0.03	0.1
Al (cmol$_c$/kg)	0.1	0.2	-0.2
Ca (cmol$_c$/kg)	0.2	-0.1	-0.2
Mg (cmol$_c$/kg)	0.3*	-0.1	-0.3*
K(cmol$_c$/kg)	0.03	-0.1	0.03
Na (cmol$_c$/kg)	0.1	-0.3	0.1
P (mg/kg)	0.4*	0.1	-0.5*
OC (%)	-0.02	0.2	-0.1
C:N	0.0	0.1	0.1
Soil H$_2$0 (%)	0.2	0.3*	-0.1
Bulk density (kg/m^3)	0.0	-0.1	0.05
MWD (mm)	0.1	0.1	-0.2
Tillage	0.1	-0.1	-0.1

At uMsinga, clay negatively correlated with pH only (r = -0.5 for pH_{KCl}), but did not seem to have an effect on all the other measured variables (Table 4.2). The silt fraction was positively correlated to K, pH, Ca and negatively correlated with C: N (r = 0.5, 0.4, 0.3 and -0.4 respectively). The sand fraction however only showed significant negative correlation with K (r = -0.2). Soil moisture was positive correlated to Na, Mg and P (r = 0.3, r = 0.4 and r = 0.3 respectively, Appendix J. 1), but was negative correlated with K and pH (r = -0.3 and -0.3). The conservation practice itself was positive correlated to bulk density, Mg, Ca and EC (r = 0.5, r = 0.3, r = 0.4 and r = 0.4 respectively, Appendix J. 1). The pH was also negative correlated to Na, C: N and exchangeable aluminium (r = -0.5, r = -0.6 and r = -0.4), but was positive correlated to K (r = 0.4).

Table 4. 2: Correlation between textural fractions and soil properties at uMsinga.

Soil properties	**Clay**	**Silt**	**Sand**
pH_{KCl}	-0.4*	0.4*	0.03
PH*w*	-0.5*	0.3*	0.1
EC (dS/m)	-0.1	-0.1	0.1
Al ($cmol_c$/kg)	-0.1	-0.2	0.2
Ca ($cmol_c$/kg)	-0.2	0.3*	0.1
Mg ($cmol_c$/kg)	0.0	0.1	0.1
K($cmol_c$/kg)	-0.1	0.5*	-0.2*
Na ($cmol_c$/kg)	0.1	-0.1	-0.0
P (mg/kg)	-0.2	-0.02	0.1
OC (%)	0.06	0.2	-0.2
C:N	0.1	-0.4*	0.2
Soil H_20 (%)	-0.1	-0.2	0.2
Bulk density (kg/m^3)	0.2	0.1	-0.2
MWD (mm)	0.1	0.01	-0.2
Tillage	-0.03	0.2	-0.1

4.4 Discussion

Communal farmers in both Bergville and uMsinga employed different conservation techniques such as contour ploughing, intercropping, ridge/furrow planting, zero tillage and fallowing in order to conserve water and soil therefore increasing crop productivity. However, conventional tillage was the most common technique used for farming. Furrow/ridge and zero tillage techniques were employed both in the fields and gardens. In a study conducted by Li *et al.*, (2007) they discovered that the ridge/furrow system does not only increase the yield of crops by improving water availability to plants within the furrows, but also protects soil and water from erosion. In Bergville under furrow/ridge planting, there were higher bases and available P compared to other techniques, whereas uMsinga had higher organic C and aggregate stability under furrow and ridge compared to other techniques.

Results showed that soil pH did not vary with depth for all the conservation practices examined serve for contour ploughing where it decreased with increasing soil depth in both areas. This was similar to the findings by Hinsinger *et al*., (2003) who discovered that pH changes in the rhizosphere depended on initial pH, plant species and nutritional constraints to which plants can respond. Comparing the different tillage techniques on pH in Bergville, fallowing, furrow/ridge and zero tillage had higher pH whereas in uMsinga zero, minimum and conventional tillage had high pH. The lower soil pH in contour ploughing (in both areas), then conventional and intercropping in Bergville and furrow/ridge and minimum tillage in uMsinga may be attributed to ploughing which aerates the soil causing the oxidation of organic matter thus releasing H^+ ions (Blevins *et al.,* 1977). Bergville generally had lower pH compared to uMsinga in all practices serve for ridge/furrow. This could be attributed to higher rainfall in Bergville than uMsinga, which results in organic matter decomposition, weathering and leaching to be more pronounced in Bergville. According to Reuss & Johnson (1986), rainfall influences the rate of soil acidification depending on the rate of water percolation through the soil profile. Water passing through the soil leaches basic cations such as Ca^{2+}, Mg^{2+} and K^+, which are then replaced by acidic cations such as Al^{3+} and H^+ (Ritchie, 1989). Decomposition and weathering increases Al saturation thus decreasing pH (van Breemen *et al.,* 1983). This was similar to our findings which showed a significant positive correlation between most bases (Ca, Mg and Na) and pH in Bergville, and a negative correlation between pH and exchangeable Al in both areas. This may be attributed to Al^{3+} which reduces soil pH to acidic level which would have an impact on availability of P and bases. Added to this, techniques such as intercropping and contour ploughing that were characterized by lower pH and high exchangeable acidity in Bergville, had lower available P and exchangeable bases when compared to other techniques. According to Ritchie, (1989) in acid organic systems, H^+ may be the dominant exchange cation. Each H^+ in the soil competes with other cations to be bonded to the negative exchange surfaces of the soil colloids. As H^+ ions displace the other cations (Ca, Mg, K), they are leached from the soil (Murata, 2003). According to Murata (2003) Al released from mineral crystals by weathering are accessible in soil solution, on exchange sites, or as constituents of exposed surfaces and each ion reacts with soluble phosphate forming relatively insoluble compounds and fixing P. There are many problems induced by pH decline such as phosphorus fixation, aluminium toxicity and root biomass reduction (Mrabet *et al.,* 2000). The decrease of P with depth in most treatments (i.e. conventional, minimum, fallowing and contour ploughing) is because of its immobility in soil. Comparing the two areas, Bergville had higher bases (particularly Ca and Mg) under zero and minimum tillage, which may be attributed to accumulation of organic material and biological activity. Minimum and zero tillage in both areas had more P, Ca and Mg compared to conventional tillage which may be due to residual accumulation, less erosion and leaching of nutrients under these two systems. In conventional tillage, soil is inverted exposing it to erosion and high infiltration which leads to loss of nutrients.

In Bergville, organic C was higher under zero tillage, contour ploughing, intercropping and minimum tillage for both the cumulative and surface (0-20 cm) C. These results agree with those of other authors who observed an effect of conservation tillage operations on improving soil quality indices (Dick, 1983; Lal *et al*., 1998), including soil organic C storage (Dick, 1983; Lamb *et al*., 1985). Conversely, increased losses of soil organic C have been documented with conventional tillage (Lamb *et al.*, 1985). The higher organic C in Bergville under these conservation practices at 0-20 cm compared to conventional ploughing may be attributed to more rapid organic matter decomposition under conventional tillage due to more frequenting ploughing. According to Carter and Rennie, (1982) soil erosion associated with conventional tillage depletes organic C on the surface depositing it down stream and/or in lower horizons. Many small scale farmers in Africa are severely affected by sheet and rill erosion, with the mouldboard plough being a major contributor to both water and wind erosion (Brunner *et al.,* 1998; Fowler, 1999). Conventional tillage generally reduces organic matter content compared to no-till and the decrease of OM leads to reduction of aggregation (Six *et al.,* 1999). This was not the case in uMsinga however as furrow /ridge, intercropping, minimum tillage and contour ploughing had the highest cumulative amounts of organic C and in the surface 0-20 cm layer as well. Again organic C at 0-20 cm depth was lowest under zero tillage compared to all other planting techniques in semi-arid uMsinga. This is similar to Six *et al.,* (2004) who observed that adoption of zero tillage in dry climates leads to an initial loss of C in the 0–30 cm soil layer for the first 5 years. This pattern has been observed in other short-term studies as well (Hendrix *et al.,* 1998). According to Deen and Kataki, (2003) changes in the soil organic matter as influenced by tillage, is more noticeable under long-term rather than short-term tillage. Organic C in uMsinga under furrow/ridge planting, contour ploughing and conventional tillage also decreased with increasing soil depth. Deen and Kataki, (2003) also noted that organic matter in the upper 10 cm soil layer of the studied soil was higher than in the 10–20 cm soil depth of the mouldboard plough treatments because of higher decomposition of OM in the upper 10 cm plough layer under mouldboard ploughing. Bergville had significantly higher clay amounts than uMsinga under zero tillage, intercropping, fallowing and minimum tillage and this could have also contributed to these techniques having better OC storage than in uMsinga.

The mean weight diameter (MWD) was used to determine aggregate stability. When compared to conventional tillage, MWD in Bergville was highest in contour ploughing and zero tillage, then lowest in minimum tillage, furrow/ridge and intercropping. Similarly, Ogunremi *et al.* (1986) reported increased proportion of aggregates exceeding 2 mm diameter in conservation tillage compared to ploughed plots, and the increases were more pronounced when no-till was combined with crop residue application. Greater soil macro-aggregation in conservation tillage systems due to reduced disturbance normally caused by ploughing has also been reported by Filho *et al*., (2002); Pinheiro *et al*., (2004). Lal (1984) also observed that crop residues and reduced tillage drastically reduced soil detachment and its transport through runoff. According to Beare *et al.,* (1994) no-tillage practices can improve soil aggregation and change the distribution and retention of soil organic matter compared with conventional tillage. In uMsinga however, practices with the highest MWD were contour ploughing, furrow/ridge and conventional tillage, while it was lowest in fallowing, intercropping and zero tillage. One may argue that minimum or zero tillage may lead to compaction of the surface soil whereas ploughing of the soil breaks down the compacted surface enhancing aggregates development. Chivenge *et al*., (2011) also found that residue retention at 0–15 cm, decreased MWD under minimum tillage than when incorporated by conventional tillage. Most techniques in Bergville had higher MWDs than in uMsinga which may be attributed to higher soil moisture in Bergville which helps in decomposition thus improving aggregate formation. On the other hand, uMsinga generally had higher bulk density than Begville in most techniques. This may be attributed to sandier soil in uMsinga than Bergville soils which had higher clay fraction and higher OC. According to Zisa *et al.,* (1980) well aggregated, porous soils and those rich in organic matter have lower bulk density. Sandy soils have relatively high bulk density since total pore space in sands is less than that of silt or clay soils (Zisa *et al.,* (1980).

4.5 Conclusion

Zero, minimum and conventional tillage had the best overall soil properties in Bergville. Zero tillage especially had consistently higher organic C, available P, aggregate stability, pH and exchangeable bases (Ca, Mg and K) in Bergville than conventional tillage. On the other hand in uMsinga, intercropping, furrow/ridge and contour ploughing performed better; with intercropping giving good levels of organic C, P and the exchangeable bases Ca, Mg, Na and K. Furrow/ridge, intercropping and contour ploughing in Bergville gave the lowest amounts of organic C, P and exchangeable bases (Ca, Mg, Na and K), while in uMsinga fallowing, conventional and minimum tillage gave the most unfavorable set of soil properties. The results also showed that techniques adopted from science namely zero, minimum and conventional tillage proved superior at improving soil properties in Bergville, while indigenous techniques such as intercropping and contour ploughing, and the scientific technique furrow/ridge were better soil quality enhancers at uMsinga. Poor performing indigenous techniques, in terms of organic C, P and the exchangeable bases Ca, Mg, Na and K from Bergville were intercropping and contour ploughing and in uMsinga it was fallowing. However poor performing techniques from science in Bergville were furrow/ridge and from uMsinga were minimum and conventional tillage. The clay fraction did not seem to have much influence on the performance of the techniques. It only negatively correlated with pH (at both sites), then lowered P and enhanced Mg availability at Bergville. In uMsinga, the silt fraction had more impact since it enhanced soil pH, Ca and K availability. As expected high soil pH improved availability of bases (Ca, Mg and Na) particularly at Bergville, but negatively correlated with Al. As a result, the higher performing techniques were unique because their performance was not influenced by textural fraction. I would recommend that farmers based in Bergville adopt zero and minimum tillage since they improved soil properties in the field. In uMsinga, intercropping and contour ploughing would be better soil quality enhancers than conventional tillage in the field, while the furrow/ridge is of more benefit in the gardens.

CHAPTER 5

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5. 1. General Discussion

This chapter gives a synthesis of the major findings, as well as the conclusions drawn and recommendations made from the study. It begins by giving an overview of the farming systems structure of selected villages in Bergville and uMsinga, and farmers' perspectives on the state of the climate of the area. It then documents indigenous soil and water management strategies, and weather indicators that farmers' use to cope with a variable climate and identifies the underlying factors that guide these choices. An evaluation was then made on the effectiveness of the conservation strategies that farmers use to enhance soil physico-chemical parameters.

5.2 Overview of the farming system of selected areas in Bergville and uMsinga

Farmers in Bergville and uMsinga rely on agriculture in the form of crop and livestock production for food and their livelihood. The farming activities of both areas included rain-fed field production of maize, sugar beans, sorghum and soybean. In the gardens there was production of horticultural crops such as vegetables (cabbages, onions, spinach, beetroot, tomatoes, and carrots), with supplementary irrigation sourced from earth dams and nearby rivers. Livestock rearing ranged from cattle, goats, sheep and pigs; while poultry mostly comprised of chickens. Unreliable weather conditions could be the reason for diversification of farming. Communal farmers have received basic agricultural training in soil and water conservation, and managing pests or disease outbreaks. Most of agricultural training was conducted by NGOs such as Land care, Philakahle, Water trust, Grain SA (in Bergville), Sinozwelo, Institute of Natural Resources -INR (in uMsinga), FSG and LIMA (in both areas). As was noted, farmers (particularly in Bergville) are keen on adopting science –based strategies of conserving soil and water. They implement these strategies from knowledge gained from these trainings to preserve soil and water. Agricultural extension workers also provide advisory services on agricultural production. Crop and livestock farming, home industries (pottery and sculptures) and social grants were the main source of income for farmers in both areas. Communal farmers especially woman are keen on farming, though climate variability has had a negative impact on crop production. This is because most women do not have any other sources of income hence they are forced to practice farming. Men, however are shifting away from farming and migrating to the cities in search for employment. The various challenges faced by farmers from both areas in agricultural production include low soil fertility, high prices of commercial fertilizers, limited water supply, lack of land tenure (especially females) and pests and diseases. These challenges are sometimes so severe that some farmers have abandoned arable cropping altogether. As a result, there was a lot of abandoned farmland lying idle. Most farmers prefer indigenous strategies to cope with limited water supply, such as using drought resistant crops (sorghum), early maturing crops (sugar beans and vegetables), intercropping (maize and sugar bean) and crop rotation (maize or millet with sugar bean or soybean). Communal farmers choose these crops mostly based on their use and adaptability to their climate and soil conditions. All crops chosen were consumable and staple foods especially maize, sugar bean and sorghum. It should be noted that farmers' perception are not consistent, so it is sometimes difficult to distinguish which techniques are really indigenous and which have been adopted from science.

5.3 Perceptions by farmers on climate trends, the coping strategies they use in extreme weather and the indigenous indicators for weather prediction

Both Bergville and uMsinga farmers have been observing changing climate patterns over the years, characterized by reduced rainfall, higher temperatures, stronger winds, more frequent thunder and hail storms, increased rainfall intensity over shorter time periods, shorter rainfall seasons and poorer rainfall distribution. In addition, uMsinga farmers assert that they have also been experiencing colder winters, warmer summers and more prolonged droughts. Studies by Ziervogel *et al.,* (2014) have also shown that mean annual temperatures in South Africa have increased by at least 1.5 times the observed global average of 0.65°C over the past five decades and extreme rainfall events have increased in frequency. These changing climatic patterns forced farmers to adopt scientific ways of soil and water conservation. Reduced rainfall made farmers to opt for furrow/ridge planting, raised beds and mulching in gardens instead of the traditional conventional tillage practiced in the field which does not conserve water and soil (hence the abandonment of field crop production by a sizeable number of farmers). Cover crops, terraces and fallowing were employed by communal farmers to mitigate higher rainfall intensity in order to improve soil infiltration and reduce erosion in order to conserve both soil and water. Furthermore, farmers are opting for short-season crops in an effort to cope with a reduced water supply e.g. vegetables, pepper, onions etc. in the gardens since these usually occupy small areas that can receive supplementary irrigation.

Farmers from both areas use various sources of climate information that include media (radio, TV and print), IKS (traditional healers and rainmakers), community leaders and agricultural advisors. The choice of information source is determined by accessibility to the media and the existence of IKS holders. An area with ready access to the media is bound to utilize it as a source of climate information, whereas whenever there are many old people with reliable climate knowledge, they can pass it on to the younger generation. There is more use of the media in Bergville, while IKS is a more reliable climate information source in uMsinga since they have limited access to television, radio, internet and print media. Infrastructural development is lower in uMsinga, as many villages are still without electricity compared to Bergville. According to INR, (2007) in uMsinga electricity supply is mainly restricted to schools, clinics and the settlements of Keates Drift, Tugela Ferry or Pomeroy therefore leaving the majority of population without electricity. Community leaders and agricultural advisors were used less frequent as sources of climate information, with the former more common in Bergville and the latter in uMsinga.

Farmers also utilize various indigenous indicators to predict the weather, in the short term, and to plan for the planting season. In Bergville, more farmers use animal behaviour than in uMsinga to predict weather. Whenever they observe calves getting excited and jumping, they assume rains would be coming in few days. Various bird species such amahlolamvula (*Apus apus*), inkonjane (*Hirundu rustica),* and isingizi/ingududu (*Buceros birconis*) are good indicators of weather in uMsinga. When the amahlolamvula (*Apus apus*) bird flies around the village, it indicates pending rain. Indigenous knowledge holders also make use of the sounds of birds to predict the coming of rains. The isingizi/ingudududu (*Buceros birconis*) birds for example indicate good rains in the coming season whenever they are heard or seen near homesteads. These findings were similar to those by Zuma-Netshiukhwi *et al.,* (2013) who discovered that local farmers utilized flock of sparrows flying around the sky, with scattered clouds, to indicate pending rain. They further elaborated that heavy migration of flocks, merging into widespread formations, forecast heavy rains approaching that particular area (Zuma-Netshiukhwi *et al.,* 2013). These indigenous indicators affect choice of crops per specific season. Some elders in Enhlesi village in uMsinga have however expressed concern that some of these indicator bird species are becoming extinct (through excessive hunting by locals), and will no longer be used for weather prediction in the near future. This shows that farmers are lacking in conservation strategies of biodiversity of these bird species, and there is need for the government to declare them as endangered species which must be preserved. In uMsinga local farmers also use sounds of frogs to predict rains. The crocking of frogs indicates pending rain, with farmers believing that frogs crock to pull rain from the sky. Predictions on the onset of rain and its possible intensity all help farmers on the types of crops and when to plant, in the short-term.

Other indigenous indicators used include cloud and wind patterns, and the shape of the moon. In Bergville strong, dense winds blowing from the Indian Ocean towards Swaziland (from east to west) called Mzansi, bring good rains which sometimes lead to floods. While in uMsinga, farmers say white, scattered clouds observed early in the morning indicate high temperatures during the day. However in both areas farmers believe dark and huge clouds bring rain. The shape of the moon was also an essential weather indicator, more so in uMsinga than Bergville. When the moon is half shaped and facing downwards, IK holders believe it will rain within a few days. On the other hand when the moon is either full or half shaped and facing upwards, it will not rain. In a study conducted in Zimbabwe by Enock, (2013), he discovered that agricultural activities were related to wind systems, migratory and mating trends of wild animals and the position of the moon. Makwara, (2013) further states that the colour of the horizon at sunrise and sunset, flowering patterns of certain plant species, appearances of rare animals and bird breeding patterns in river valleys were used in drought and flood prediction so as to ensure more focused farming that prepares for hazardous climatic conditions.

Equipped with this knowledge of weather prediction, farmers in both areas then also utilize various indigenous strategies to cope with climate extremes as well as plan for their farming activities. In the event of droughts, they rely on rainmakers and consult with traditional healers to bring rains. They also plant drought resistant crops such as sorghum/millet, and use drought tolerant varieties such as yellow maize, that are able to withstand dry spells. During floods events, farmers open drainage pathways in their fields, gardens or even at home to remove excess water and flooding. Whenever there are thunderstorms or lightning, incense is burnt to protect the household and individuals from attack. Moreover during pests and disease outbreaks, farmers who cannot afford expensive pesticides and herbicides have their own indigenous methods to treat and prevent diseases. Both livestock and crops are smeared with cow dung to heal wounds and avoid pest attacks respectively. Ashes are also used on vegetables in gardens to prevent grasshoppers from feeding on them. Communal farmers also use soap solution on the crops to treat disease and pests. They also crush the aloe plant then spray it on crops to treat diseases.

5.4 Soil and water conservation strategies utilised to mitigate limited water availability

In order to meet food demand, strategies to increase crop production and mitigate climate variability are needed. Innovations from science must not come at the expense of IKS however, but must aim to complement it. Communal farmers must be included in research, and their views should also be valued. Though Bergville and uMsinga farmers have been exposed to scientific soil and water conservation methods, IKS are still used in both fields and gardens. Bergville farmers utilise scientific methods such as zero tillage, terraces and mineral fertilizers in crop production. In uMsinga more farmers use indigenous methods such as manure addition, incorporation of crop residues and contour ploughing to enhance soil fertility. Many farmers in uMsinga prefer indigenous strategies because they are easy to use and readily available on their homesteads. Challenges to use of IKS e.g. animal manure is that it is often of poor quality and insufficient to apply on the whole field. Animal manure is therefore mostly restricted to application on gardens, since they are smaller compared to whole fields. Bergville farmers mostly use mineral fertilizers, zero tillage and mulches in gardens and small fields to improve soil fertility. They have adopted these scientific techniques because they improve yields. After application of mineral fertilizer and pesticides farmers obtain better yields in terms of quantity in a short term. Again, as it has been stated in Chapter 4, communal farmers practicing zero tillage and minimum in the field and furrow and ridge planting in gardens had better soil physio-chemical properties hence crop yields can be easily improved. Farmers in both areas are willing to adopt new technology that improves agricultural productivity. The hindrances to adoption are lack of technical know-how, limited capital for initial investment or to sustain the technology, and inability of technology to cause immediate yield gains.

The organizations that have promoted adoption of conservation techniques are FSG, Sinozwelo, Philakahle, DWARF, GrainSA and Water trust. These organisation trained farmers on rainwater harvesting (using tanks and buckets), crop rotation, use of cover crops and mulch. Bergville farmers are more keen to adopt techniques offered by researchers than uMsinga farmers. One can argue that uMsinga has poorer infrastructural development, and farmers lack the technical know-how and capital to sustain the technology in the long term. uMsinga also experiences severe droughts which hinder farmers from experimenting with new technologies leading to project failures (INR, 2007). Hence agricultural production is declining in this area, escalating poverty and food insecurity.

5.5 Impact of the different soil and water conservation strategies used on soil productivity

Contour ploughing, furrow/ridge planting, intercropping, fallowing, zero, minimum and conventional tillage were common techniques practiced by farmers in Bergville and uMsinga. These techniques (except conventional tillage), were employed to conserve soil and water in an effort to increase crop yields. In Bergville zero, minimum and conventional tillage enhanced soil properties (aggregate stability, pH, bases, OC and P) better than the other techniques. Zero tillage especially had consistently high organic C, available P, aggregate stability, pH and exchangeable bases (Ca, Mg and K) in Bergville. However in uMsinga intercropping, contour and furrow/ridge performed better, with intercropping giving high levels of organic C, P and the exchangeable bases Ca, Mg, Na and K. The poorest performers in Bergville were furrow/ridge, intercropping and contour ploughing, while in uMsinga fallowing, conventional and minimum tillage gave the most unfavourable set of soil properties. The results also showed that techniques adopted from science namely zero, minimum and conventional tillage proved superior at improving soil properties (aggregate stability, pH, bases, OC, soil moisture, and P) in Bergville, while indigenous techniques such as intercropping and contour ploughing, and the scientific technique furrow/ridge were better soil quality enhancers at uMsinga. Poor performing IK techniques from Bergville were contour ploughing and intercropping and in uMsinga it was fallowing. On the same note, poor performing techniques from science in Bergville was furrow/ridge and from uMsinga were conventional and minimum tillage. The clay fraction did not seem to have much influence on the performance of the techniques. It only negatively related with pH (at both sites), then lowered P and enhanced Mg availability at Bergville. In uMsinga, silt had more impact since it enhanced soil pH, Ca and K availability. In Bergville silt negatively impacted Na availability. As expected high soil pH enhanced availability of bases (Ca, Mg and Na) particularly at Bergville, but negatively correlated with Al. However, correlation analysis results showed that there was no relationship between the different particle size fractions and tillage techniques. As a result, the higher performing techniques were unique because their performance was not influenced by textural fraction.

5.6 Conclusions and Recommendations

The indigenous indicators used by Bergville and uMsinga farmers to predict weather (e.g. animal and bird behaviour, moon shape, wind and cloud patterns) though reliable, can only be used for short term weather predictions and cannot be used for long term climate predictions. They are good as they help farmers plan their farming in the short term. Further studies should be done to relate weather data with predictions based on IKS. More efforts should also be made by policy makers and government officials for communal farmers to have access to long-term weather data (particularly from their localities) in order to make more informed long term climate forecasts. They can use these to complement their indigenous methods of weather prediction. The indigenous strategies that proved useful to manage extreme weather events were using rainmakers to bring rains, opening pathways to minimize floods and using the aloe plant and cow dung to control crop diseases and pests could be recommended for adoption. Other strategies that can be adopted to cope with drought are the use of drought tolerant crops and cultivars, farm diversification, early planting, intercropping and crop rotations. Yellow instead of white maize varieties in particular, can withstand drier climates better, while rotations of cereals, legumes and vegetables can help cope with a limited water supply.

Limited water supply (particularly in uMsinga), poor soil fertility, expensive commercial fertilizers, inadequate and low quality organic fertilizers were major contributors to low yields in both areas. Soil and water conservation strategies that were effective at enhancing soil fertility in Bergville were zero, minimum and conventional tillage, whereas in uMsinga intercropping, furrow/ridge and contour ploughing were better. Farmers based in Bergville need to adopt zero and minimum tillage for improved soil properties in the field. In uMsinga, intercropping and contour ploughing would be better soil quality enhancers than conventional tillage in the field, while the furrow/ridge is of more benefit in the gardens. These strategies can also be enhanced by teaching farmers on how to manufacture cheap organic fertilizers from locally available organic resources such as manure, plant residues and household waste through composts, mulches or use of cover crops. A number of farmers from the area were also practicing other sustainable practices such as crop rotation, intercropping and cover crops which can be up-scaled to other areas. Conservation tillage plays a critical role in conserving soil and water henceforth local farmers have to be trained more in these through emphasizing and funding related research in an effort to encourage their adoption.

Farmers in both areas are keen to adopt and learn new farming techniques, as long as the new methods will improve crop production. More efforts by government and researchers needs to be put in supporting farmers, particularly in the initial establishment of a particular technology, until they get full expertise on how to sustain it in the long run. Some private organisations (Land care, Philakahle, Water trust, Grain SA, Sinozwelo, INR, FSG and LIMA) and a few government departments (agriculture, social development and water affairs) have been making efforts in this regard in Bergville and uMsinga but more still needs to be done. The study recommends that policy makers should promote the inclusion of indigenous knowledge systems used by farmers in weather prediction, managing extreme weather events, and in soil-water management to ensure sustainable agricultural systems. Furthermore, technologies should also be developed with farmers' perceptions in mind to ensure their long-term sustainability.

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APPENDICES

Appendix A. 1: Questionnaire used in the baseline survey at Msinga and Bergville

This questionnaire is not compulsory; the respondent may withdraw their participation at any time, should they so wish.

Objective: The aim of the survey is to document communal farmers' adapting and coping strategies on soil and water management under a variable climate.

Enumerator Name …………………… Date of interview:

District Name…………………… Ward Name ……………………..

Village name…………………………

Agroecological zone:

1. Arid zone (≤ 350 mm) ☐
2. Semi-arid zone (351- 550 mm) ☐
3. Sub-humid zone (551- 800 mm) ☐
4. Humid zone (801- 1000 mm) ☐
5. Temperate (> 1000 mm) ☐

Farm type: 1. Communal ☐ 2. Small Scale Commercial ☐

GPS Reading:

HOUSEHOLD INFORMATION and agriculture systems

1. **Interviewee:**………………………………………

   a. Sex of household:
      1. Male ☐ 2. Female ☐
   b. Age of Household head:
      <30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐
      > 70 ☐ Unknown ☐
   c. Any agricultural training Yes ☐ No ☐
   d. Is the head resident on the farm? Yes ☐ No ☐

2. Is farming the main activity in the farm?

1. Yes ☐ 2. No ☐

3. What are your sources of income? (Tick first column as appropriate and rank levels of source of income in the second column – 1 for highest income)

	Rank
1. Crop farming	☐
2. Livestock and products	☐
3. Home industries	☐
4. Poultry farming	☐
5. Salary / wages	☐
6. Other (specify) ……………………….	

4. What sort of challenges do you face in crop farming?

	Rank
1. Low soil productivity/ fertility	☐
2. High prices of commercial fertilizer	☐
3. Limited water supply/erratic rainfall patterns	☐
4. Limited labour	☐
5. Land tenure	☐
6. Other (specify)………………………………….	

Crop

5. What crops do you grow at present? (Tick first column as appropriate and rank levels of crops grown in the second column – 1 for mostly grown crop)

	Rank
1. …………………	☐
2. …………………	☐
3. …………………	☐
4. …………………	☐
5. ………………….	☐

1. How do you select the crop(s) to grow

Rank

   1. Early maturity ☐
   2. Resistance to disease ☐
   3. Resistance to drought ☐
   4. High yield potential ☐
   5. Easy market access ☐
   6. Easy management of cop ☐
   7. Human consumption ☐
   8. Other (specify)
2. What cropping strategy is adopted during dry season to cope with limited water availability?

   Rank

   1. Use drought resistant cultivar ☐
   2. Drought resistant crop ☐
   3. Short season or early maturing crop ☐
   4. Crop rotation ☐
   5. Mixed cropping ☐
   6. Revising the planting date ☐
   7. Change the plant density ☐
   8. Other (specify) ☐
3. Where do you get ideal information/recommendations about high productivity, early maturity of crop, crop resistant to drought, pests and drought?

   Rank

   1. The elderly ☐

   2. Agricultural extension workers ☐

   3. Community leaders’ ☐

   4. Media (TV, radio, newspaper and books) ☐

   5. Other (specify)…………………..

4. What is your source of water for crop production?

Rank

   1. Rain-fed ☐

   2. Irrigation system ☐
   3. Other (specify)…………………

   4. In the event of prolonged droughts, which crops do you grow and why?

Rank

1……………………………. ☐

2……………………………. ☐

3……………………………. ☐

4……………………………. ☐

5……………………………. ☐

6…………………………….. ☐

5. Which crops were cultivated in the past?

Rank

1……………………………. ☐

2……………………………. ☐

3……………………………. ☐

4……………………………. ☐

5……………………………. ☐

6…………………………….. ☐

7 ……………………………. ☐

7. What were reasons for changing cultivars and crop types?

	Rank
1. Reduced rainfall	☐
2. Opted for drought resistant	☐
3. High input requirements (seed, fertilizer, labour)	☐
4. Higher temperatures	☐
5. Advised by extension workers	☐
6. Reduced soil fertility	☐
7. Limited markets to sell produce	☐
8. Other (specify)………………………	

Livestock

7. Numbers and livestock + poultry species kept

	Rank
1. Cattle	☐
2. Sheep	☐
3. Goats	☐
4. Chickens	☐
5. Pigs	☐
6. Others (specify)……………….	

1. Why do you keep the livestock above?

	Rank
1. Meat	☐
2. Milk	☐
3. Manure	☐
4. Blood	☐
5. Skin	☐
6. Cash from sales	☐
7. Investment	☐
8. Cultural ceremonies	☐
9. Other (specify)……………	

2. The reason for poultry farming?

	Rank
1. Eggs	☐
2. Feathers	☐
3. Meat	☐
4. Cash from sales	☐

5. Other (specify)……………

3. What sort of challenges do you face in livestock/poultry farming?

		Rank
1.	Poor quality breeds	☐
2.	Inadequate local feed supply	☐
3.	High prices of commercial feed	☐
4.	Limited water supply	☐
5.	Pest and disease outbreaks	☐
6.	Limited labour	☐
7.	Limited technical know-how	☐
8.	Limited access to markets	☐
9.	Other (specify)…………………………………	

4. Who owns these livestock? (Can tick more than one)

1. Head ☐ 2. Spouse ☐ 3. Head/spouse together ☐
4. Child/Children ☐

3. How did you acquire your livestock? 1. Inherited☐ 2.Given☐ 3. Bought☐
Others specify………

5. How are livestock fed during times of limited feed?

(a) Supplementary feed ☐ (b) Scavenging feed ☐

(c) Others (specify)……………………

6. If there is supplementary feed, what type of feed do you provide?

	Rank
1. Plant residual	☐
2. Commercial concentrate ration	☐
3. Hay	☐
4. Whole grain	☐
5. Others (specify)……………………	

7. What is the source of water for livestock?

Rank

a. Open water source e.g dams, rivers etc ☐

b. Borehole ☐

c. Other (specify)………..

8. How do your livestock cope with limited water availability during the dry season?

Rank

(a) Animals go to water ☐

(b) Water is provided (borehole, pumps) ☐

(c) Both ☐

(d) Other (specify)………..

Climate change

4. What is your understanding of climate change?

Rank

a. High temperatures ☐

b. Reduced rainfall ☐

c. Change in rainfall pattern ☐

d. Change in rainfall intensity ☐

e. Change in planting growing season ☐

f. Stronger winds

g. Other (specify)…………………………

5. What is the length of your rainfall season?

Rank

a. September-March ☐

b. September-April ☐

c. November-April ☐

d. August- mid February ☐

e. November- March ☐

f. September-end February ☐

g. Other (specify)…………………………

6.Has it changed from previous years?

Yes ☐
No ☐

1. Where do you get information about climate variability?

Rank

1. Media ☐
2. Indigenous knowledge ☐
3. Agricultural advisors ☐
4. Community leaders ☐
5. Other (Specify)………………………

2. Which climate information source is more reliable?

Rank

1. Media ☐
2. Agricultural advisors ☐
3. Community leaders’ ☐
4. Other (Specify)……………..

3. What do you use to predict climate variability?

Rank

1. Weather station ☐
2. Indigenous indicators ☐
3. Other (specify)………………..

4. Which indigenous indicators are in place to predict weather?

Rank

1. Animal behavioural patterns ☐
2. Bird behaviour ☐
3. Insect Indicators ☐
4. Wind patterns ☐
5. Solar system and stars ☐
6. Cloud patterns ☐
7. The shape of the moon ☐
8. Other (specify) ………………..

6. Which indigenous practices are adapted to cope with climate extremes that include the following;

Rank

a. Droughts
    1. Rain dance ☐
    2. Praying at the mountain ☐
    3. Consultation with traditional healers ☐
    4. Other (specify)……..

b. Floods

Rank

    1. Building material and construction style ☐
    2. Wooden bridges ☐
    3. Pathways for water ☐
    4. Mud embankments ☐
    5. Culverts ☐
    6. Bedding ☐
    7. Ridges and furrows planting ☐
    8. Other (specify)…………

c. Thunderstorms

Rank

    1. Beating drums ☐
    2. Burning snake ☐
    3. Release sticks ☐
    4. Strengthen household (traditional rituals) ☐
    5. Spear pointing ☐
    6. Indigenous herbs
    7. Other (specify)………………..

d. Pests/ disease outbreak

Rank

1. Bio-pesticides ☐
2. African potato ☐
3. Burning of stalks ☐
4. Animal culling ☐
5. Cutting affected branches ☐
6. Smearing with cow dung ☐
7. Spraying with sunlight solute ☐
8. Other (specify)…………………..

7. What measures are in place to out-scale IKS in climate variability management?

Rank

1. Field days and demonstration trials ☐
2. Farmers forum ☐
3. Observation ☐
4. By word of month ☐
5. Other (specify)…………………………..

Water

12. How do you adapt to low rainfall and higher temperatures (both livestock and crops)?

Rank

(a) Resistant plant and livestock ☐

(b) Building dams ☐

(c) Feeding livestock ☐

(d) Early maturing cultivar ☐

(e) Irrigation system ☐

(f) Other (specify)…………….

13. What indigenous methods do you utilize to preserve soil and water during crop farming?

Rank

1. Harvest rain water (using open bucket) ☐

2. Construct earth dams' ☐

3. Construct pit (water storage) ☐

4. Adding manure ☐

5. Contour farming ☐

6. Fallow farming ☐

7. Mulching ☐

8. Furrow/ridge planting ☐

9. Rehabilitating degraded areas (terraces using stones) ☐

10. Cover crops ☐

11. Raised bed ☐

11. Other (specify)…………….

14. Which Soil Water Conservation Technique (SWCT) have you adopted that is offered by researchers?

Rank

1. Harvest rain water (using open bucket) ☐

2. Construct pit (water storage) ☐

3. Contour farming ☐

4. Fallow farming ☐

5. Mulching ☐

6. Furrow/ridge planting ☐

7. Rehabilitating degraded areas (terraces using stones) ☐

8. Cover crops ☐

9. Raised bed ☐

10. Zero tillage ☐

10. Other (specify)…………….

15. Have you received any training in soil and water management?

Yes ☐

No ☐

16. From whom did you get this training?

	Rank
1. Agricultural extension	☐
2. NGOs (name the NGO)	☐
3. Community Leaders	☐

4. Others (specify)…………..

17. Are locals, communal farmers, keen on adopting soil and water conservation technologies (SWCT) offered by researchers?

Yes ☐

No ☐

18. Which SWCT offered by science is more popular in the community and why?

	Rank
1. Water harvesting technique (pits, dams, ditches)	☐
2. Contour farming	☐
3. Zero tillage	☐
3. Rehabilitating degraded areas (stone terraces)	☐

4. Other (specify)………………………………….

19. How are the comparisons in yield, soil fertility and S and W conservation, between indigenous S and W conservation and the scientific ones? (Every number has both Indigenous and science).

1. **Manure, fertilizer**
2. **Furrow/ contour planting, zero tillage**
3. **Pit/ earth dams, tanks**
4. **Rain water harvest using bucket, tanks**

	Indigenous	**Science**
Yield		

Soil fertility

S and W cons

Non Timber Forest Products (NTFP) and forest reserves

1. Which NTFP and forest products are mostly used by communities?

	Rank
1. Wood	☐
2. Thatch grass	☐
3. Medicinal plants	☐
4. Indigenous vegetables	☐
5. Fruits	☐
6. Mushroom	☐
7. Tree bark	☐
8. Other (specify)…………………………..	

2. What indigenous systems are in place to preserve NTFPs and forest products?

	Rank
1. Sacred forests	☐
2. Godly fruits	☐
3. Rotational grazing	☐
4. Forestry controlled by king and chief	☐
5. Other (specify)………………………….	

Appendix B. 1: The ANOVA of soil pH in Bergville and uMsinga.

i) Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicates.*Units* stratum					
Tillage	13	334.3394	25.7184	31.74	<.001
Depth	2	1.0403	0.5201	0.64	0.527
Tillage.Depth	26	5.8665	0.2256	0.28	1.000

Appendix C. 1: The ANOVA of exchangeable acidity in Bergville and uMsinga.

Variate: Exchangeable acidity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicates.*Units* stratum					
Tillage	13	297.6706	22.8977	56.49	<.001
Depth	2	4.0125	2.0062	4.95	0.008
Tillage.Depth	26	10.0286	0.3857	0.95	0.535
Residual	390	158.0815	0.4053		

Appendix D. 1: The ANOVA of bases in Bergville and uMsinga.

Analysis of variance0736837806

Variate: Bases

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicates.*Units* stratum					
Tillage	13	2285.30	175.79	7.64	<.001
Depth	2	100.65	50.33	2.19	0.114
Tillage.Depth	26	404.99	15.58	0.68	0.885
Residual	390	8972.45	23.01		

Appendix E. 1: The ANOVA of available P in Bergville and uMsinga.

Analysis of variance

Variate: Available P

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicates.*Units* stratum					
Tillage	13	107666.	8282.	5.00	<.001
Depth	2	40604.	20302.	12.25	<.001

Tillage.Depth	26	66660.	2564.	1.55	0.044
Residual	390	646379.	1657.		

Appendix F. 1: The ANOVA of Organic C in Bergville and uMsinga.

Analysis of variance

Variate: OC

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicates.*Units* stratum					
Tillage	13	21.6933	1.6687	7.48	<.001
Depth	2	170.5468	85.2734	382.29	<.001
Tillage.Depth	26	38.2463	1.4710	6.59	<.001
Residual	390	86.9930	0.2231		

Appendix G. 1: The ANOVA of aggregate stability in Bergville and uMsinga.

Analysis of variance

Variate: Aggregate stability

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replic.*Units* stratum					
Tillage	13	146.5829	20.9404	177.28	<.001
Residual	88	10.3945	0.1181		

Appendix H. 1: The ANOVA of bulk density in Bergville and uMsinga.

Analysis of variance

Variate: bulk density

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replic.*Units* stratum					
Tillage	13	574623.	82089.	49.69	<.001

Residual	88	145391.	1652.

Appendix I. 1: The ANOVA of particle size fraction in Bergville and uMsinga.

i) Analysis of variance

Variate: Sand

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Depth.*Units* stratum					
Tillage	13	18772.9	1444.1	12.05	<.001
Residual	130	15576.6	119.8		

ii) Analysis of variance

Variate: Silt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Depth.*Units* stratum					
Tillage	13	3723.80	286.45	6.08	<.001
Residual	130	6121.79	47.09		

iii) Analysis of variance

Variate: Clay

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Depth.*Units* stratum					
Tillage	13	5588.28	429.87	5.08	<.001
Residual	130	10993.87	84.57		

Appendix J. 1: Correlation between soil fraction and soil properties.

	Msinga																
Tillage	1,000000																
pH$_{KCl}$	-0,080496	1,000000															
EC	0,360632	-0,054543	1,000000														
Soilw	0,005063	-0,448818	0,149577	1,000000													
OC	0,132049	0,117527	-0,190783	0,068346	1,000000												
Al	0,005063	-0,448818	0,149577	1,000000	-0,068346	1,000000											
P	-0,144294	0,001526	0,043190	0,305886	0,200720	0,305886	1,000000										
C;N	-0,035093	-0,583874	0,130737	0,419441	-0,227249	0,419441	-0,001644	1,000000									
Ca	0,443917	0,090334	0,009592	0,132771	0,240135	0,132771	0,054788	0,028645	1,000000								
Mg	0,259173	-0,233542	-0,175284	0,381467	0,386056	0,381467	0,146956	0,056378	0,670150	1,000000							
K	0,015573	0,428438	-0,147377	-0,343675	0,226367	-0,343675	0,241038	-0,182737	0,352307	0,049660	1,000000						
Na	-0,025509	-0,464009	-0,151052	0,335195	-0,021010	0,335195	-0,110118	0,341024	-0,344977	0,103561	-0,365346	1,000000					
bulk	0,471862	-0,071353	0,110781	-0,195789	0,164569	-0,195789	-0,095171	0,047201	0,081674	0,125218	0,160781	0,182050	1,000000				
ageg	0,008140	-0,085818	0,000604	-0,099372	0,224277	-0,099372	0,125981	-0,098287	-0,075767	-0,028334	0,299513	-0,083221	0,177446	1,000000			
clay	-0,026799	-0,355758	-0,130408	-0,114802	0,062070	-0,114802	-0,176034	0,045963	-0,224867	0,029541	-0,127744	0,124608	0,177163	0,076488	1,000000		
silt	0,223026	0,338729	-0,137423	-0,162413	0,236586	-0,162413	-0,015492	-0,353489	0,253311	0,102013	0,484393	-0,118706	0,068578	0,013800	-0,025612	1,000000	
sand	-0,085476	-0,027864	0,121986	0,183097	-0,184438	0,183097	0,144411	0,164158	0,135881	0,091472	-0,238917	-0,009484	-0,171105	-0,218336	-0,577749	-0,583449	1,000000
	Tillage	pH$_{KCl}$	EC	Soilw	OC	Al	P	C;N	Ca	Mg	K	Na	bulk	ageg	clay	silt	sand
	Bergville																
Tillage	1,000000																
pH$_{KCl}$	-0,366149	1,000000															
EC	0,274688	-0,042152	1,000000														
Soilw	-0,044358	-0,001736	-0,134987	1,000000													
OC	-0,157335	-0,112639	0,039059	0,262988	1,000000												
Al	0,420561	-0,816301	0,131226	-0,028994	0,146611	1,000000											
P	-0,068659	0,062618	-0,042021	0,066944	0,068709	0,070041	1,000000										
C;N	0,037176	0,045530	-0,195924	-0,041680	-0,037215	-0,064134	-0,127283	1,000000									
Ca	-0,238032	0,412848	-0,171445	-0,126435	0,172451	-0,564704	-0,020413	-0,059119	1,000000								
Mg	-0,270037	0,385894	-0,230919	-0,059319	0,107774	-0,579727	-0,036927	-0,117952	0,958876	1,000000							
K	-0,141206	0,086828	0,066324	0,003585	-0,097508	-0,115747	0,269911	-0,239681	0,424298	0,396054	1,000000						
Na	-0,125959	0,280723	0,018792	-0,483544	-0,422365	-0,240198	-0,110573	-0,189310	0,121564	0,111057	0,132087	1,000000					
bulk	0,067828	-0,062187	0,111152	-0,154901	-0,041567	-0,028090	0,104874	-0,052416	0,046491	0,050137	-0,020049	0,145993	1,000000				
ageg	-0,132894	-0,144647	-0,056100	0,068755	0,052768	0,074593	0,077043	-0,143858	-0,078667	-0,006381	0,002272	0,002001	0,392521	1,000000			
clay	0,051582	-0,368266	-0,142893	-0,218413	-0,016067	0,114847	-0,426117	0,002390	0,206760	0,266515	0,028153	0,064312	0,003176	0,085418	1,000000		
silt	-0,102244	0,026165	-0,029745	0,276822	0,182303	0,064789	0,093457	0,059886	-0,070328	-0,088165	-0,141165	-0,267563	-0,115984	0,068525	-0,469104	1,000000	
sand	-0,077679	0,468318	0,122494	0,127002	-0,103761	-0,180162	0,455533	0,065661	-0,199861	-0,279090	0,034086	0,052377	-0,048057	-0,155481	-0,764296	0,066942	1,000000
	Tillage	pH$_{KCl}$	EC	Soilw	OC	Al	P	C;N	Ca	Mg	K	Na	bulk	ageg	clay	silt	sand