SUSTAINABLE AGRICULTURE AMONG SUBSISTENCE FARMERS IN SWAZILAND: A STUDY OF ADOPTION AND PRACTICE OF CONSERVATION AGRICULTURE AT SHEWULA

by

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PREFACE

The study analyses the success (or otherwise) of the introduction of conservation agriculture in Swaziland. It attempts to document baseline information on various aspects of the introduction of conservation agriculture in Swaziland using the Shewula chiefdom as a case study. The study is divided into five separate but related components and presented below as separate but related papers intended for publication. It is for this reason that each chapter concludes with a set of references, rather than the more conventional format of presenting all the references at the end of the thesis. These components (or chapters) of the study were informed by the specific objectives of the study which include the following:

a) To investigate the prospects and challenges of adoption of conservation by the local subsistence farmers in Swaziland.
b) To establish the status of crop cultivation, cropping pattern and factors guiding selection of crops for cultivation among the rural people of Swaziland (as opposed to commercial agriculture).
c) To study the level and pattern of adoption of conservation agriculture among the traditional, rural people of Swaziland, as illustrated by the Shewula chiefdom.
d) To assess the extent of soil cover and accumulated crop residue and their influence on soil moisture and organic matter content in the traditional context in the country, and
e) To conduct a comparative analysis of organic matter and nutrient content in soils under conservation agriculture and conventional traditional farming in Swazi Nation Land.

The data for the study were collected from various primary and secondary sources. The literature review yielded secondary data and was conducted in various areas including the University of Swaziland Library, Government of Swaziland and Non-Government Agencies resident in Swaziland, the Life Sciences Library at the University of KwaZulu-Natal in Pietermaritzburg as well as various internet websites. The FAO Office in Mbabane was a crucial source of information on the implementation of conservation agriculture project in Swaziland. The researcher was not part of the FAO's project on conservation agriculture but closely studied its implementation. Primary data was collected using the survey (questionnaire) where more than 300 farmers were interviewed; soil sampling conducted yielded some 60 soil samples which were analyzed and other data collected by direct observation of homesteads and cultivation methods, and lengthy discussions with the farmers, at Shewula in Swaziland.

The findings of the study reveal that the potential for the adoption of conservation agriculture exists, although the adoption level is currently low. Although there is no direct association between the adoption of conservation agriculture and cultivation of what is viewed by the people as 'traditional crops', such crops were, however, promoted for cultivation by the project introducing conservation agriculture in the country. The study has shown that the local farmers cultivated mainly traditional crops (including what they view as traditional strains of maize). This decision appears to be largely motivated by factors such as a perceived better drought tolerance and resistance to pests. The study also revealed the potential of conservation agriculture to contribute to improving soil pH, soil moisture retention, and organic matter content as well as increased levels of soil nutrients.

The experimental work and other analyses described in the thesis were carried out at the University of Swaziland and Intertek Testing Services (SA) (Pty) Ltd in South Africa between March 2004 and September 2014 under the supervision of Prof. H.R. Beckedahl.

DECLARATION

I hereby declare that the work submitted in this thesis is my original research which I have conducted unaided except where otherwise indicated, and has never been submitted for any degree or examination at any other university.

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Professor H. R. Beckedahl

ABSTRACT

The study comprises five separate but related research papers intended to document the introduction and adoption of conservation agriculture in Swaziland and the status of crop cultivation in this country. It further provides empirical evidence on adoption and performance of conservation agriculture in improving the soil production capacity. The study was conducted at Shewula in Swaziland and employed a mixed methodological approach that included literature review, questionnaire interviews (survey), focus group discussions and laboratory analysis of soil samples. Ethical clearance was acquired from the institution's ethical clearance committee which approved all the instruments for data collection used in the study. Moreover, the candidate made an undertaking to hide identities of all respondents that were interviewed during the study. The study investigated the prospects and challenges of adoption of conservation agriculture and established that there were high prospects for the adoption of conservation agriculture. It also established that farmers were cultivating traditional crops while intercropping was the paramount crop cultivation pattern which was viewed as significant to facilitate the adoption of conservation agriculture in the country. The study of the level and pattern of adoption of conservation agriculture revealed a very low adoption level of the system since only about 5% of the farmers were practicing the system more than 10 years after its introduction to the area. Adoption level varied with the socio-economic context of the farmers and was mainly on an experimental basis. The influence of basic conservation agricultural practices on soil moisture and organic matter content revealed that some farmers were able to achieve the requisite minimum soil cover of 30% though problems of crop residue management were observed. Moreover, levels of moisture and organic matter content were significantly higher in soils under the system than those under conventional farming. The study concluded that conservation agriculture has a positive influence on retention of soil moisture and organic matter content not only for organised agriculture (where this is well documented), but also at the level of the subsistence farmer. A comparative analysis of soil pH and levels of nutrient content in the soil under conservation agriculture and conventional farming did not reveal significance different between the two farming systems. The soils were generally acidic with an average pH of 5.0 while the Student *t* test performed indicated that the difference between the two farming systems in terms of nutrient content levels was not significant (*p > 0.005, df. at 18)*. Although the pH and nutrient content levels did not show significant differences between the two farming systems, however, the levels were slightly higher in the soil under conservation agriculture. The study argues that cconservation agriculture has the potential to stabilize soil pH and to improve nutrient content, and the observed lackluster performance of the system to have higher nutrient content compared to conventional farming is attributed to improper management of soil cover and crop residue. This leads to the conclusion that compelling factors exist in facilitating the adoption of the system in Swaziland especially along the conservation agriculture awareness project focus and other information emerging from the study, centered largely around a conflation of

the principles of conservation agriculture, and the use of indigenous seed strains. However, there are still challenges pertaining to particular aspects of conservation agriculture especially retention of crop residue which raises questions about the current animal husbandry practices.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

The study benefited tremendously from the generous support and participation of the farmers practicing conservation agriculture in the Shewula chiefdom, the study area. The farmers, besides giving the researcher unlimited access to their plots, also provided valuable insight and details on how conservation agriculture is practiced in their area. Special mention needs to be accorded to the farmers pioneering conservation agriculture in the area, who included the following women: Make Tfumbatsa, Make Mashwama and Make Dladla. The researcher is also indebted to Mr. Ndumiso Masimula, FAOs Conservation Agriculture Coordinator, who provided valuable information about the system and its practice at Shewula and in the whole country. Gratitude is also extended to all the 313 farmers who responded and participated in the survey. The study also benefited from assistance diligently offered by the researcher's former students who helped in various ways, including the administration of questionnaires, collection and preparation of soil samples, laboratory analysis as well as data input. My colleagues in the Faculty of Agriculture at the University of Swaziland offered valuable advice and expertise in the various soil tests that were conducted in the Faculty's soil science laboratory. Lastly, Intertek Testing Services in Johannesburg, South Africa deserves mention for conducting a number of analyses that could not be undertaken within the institution due to lack of equipment and capacity.

May I also make a special mention of my family, wife and children, who supported me during the long periods of my absence either collecting data at Shewula or conducting literature review and doing write up at the University of KwaZulu-Natal, Pietermaritzburg. Further, I would like to acknowledge the support of my colleagues in the department and Faculty who never failed to convey words of encouragement to me. Last but not least I would like to convey my utmost appreciation to Prof. H.R. Beckedahl for holding my hand and leading me through the lengthy and challenging path of conducting research at the PhD level. Prof. Beckedahl's patience was the main motivation that kept me focused on my research despite the many activities that threatened to curtail progress in my studies.

CHAPTER 1

INTRODUCTION

1.1 CONSERVATION AGRICULTURE IN THE GLOBAL CONTEXT

Agriculture, simply defined as the science and art of producing crops and animals, is the most vital activity for the livelihoods of the human being as well as of its dependents (Rahman, 2013). Its origins are traced back to the early civilization, but it has progressed rapidly over the years to be the main source of livelihood for the ever increasing population in the world. Livelihood denotes the way in which living is obtained and comprises capabilities, assets and activities required for a means of living (Ellis, 2000; DIFID, 1999). To be meaningful livelihoods have to be sustainable and currently the sustainability of sources of livelihood in many sub-Saharan African countries is being questioned amid the prevailing decline in crop yields and loss of soil fertility. Sustainability is understood in the study as having to do with continuance or persistence of an identified activity or system over a long period of time (Ellis, 2000; Ellis & Briggs, 2001). Agriculture, the main source of livelihood in sub-Saharan Africa is performing poorly especially under the current threats of climate change and variability rendering many people prone to food shortages and poverty. It was observed as early as the 1980s that without agricultural growth attempts to achieve food security and poverty alleviation would be futile (Singh, 2004).

Attempts to improve the agricultural sector were dominated by 1950s and 1960s paradigms of agricultural modernization and focus on large-scale farm operations which were irrelevant to the development of the rural subsistence agricultural sector (Ellis & Briggs, 2001). In sub-Saharan Africa these were reflected in the Integrated Rural Development Approach of the 1970s and 1980s which focussed on provision of modern services and proved unhelpful as far as promotion of rural livelihoods was concerned (Jonhston & Clark, 1982). The Green Revolution in the 1960s increased production of cereal crops, particularly rice to help countries progress towards the food-self-sufficiency goal. Crop production was mainly through mono-cropping on huge farms relying extensively on chemical pesticides, synthetic fertilizers, irrigation and genetically modified crop varieties. These practices tend to deplete and degrade soil, reduce biodiversity, and generate air and water pollutants that degrade the environment and threaten the health of human beings (Rahman, 2013; FAO, 1998). Actually, agricultural pollutants are regarded as important causes of climate change and the plants and animals are losing their capability to resist from the environmental vulnerabilities. Modern farming technology inherent in the Green revolution proved unaffordable to small holder farmers and inevitably failed to make any positive impacts improving the subsistence agricultural sector. Hence the rural people's food and nutrient security have been deteriorating over the years despite the significant research and technological advancements made in conventional farming techniques (Khan, 2004). These developments necessitated a paradigm shift in farming techniques and transition towards sustainable and climate smart agricultural techniques, particularly where human population is closely reliant on agricultural production such as Swaziland.

The paradigm of sustainable agriculture recognises the need for participation and empowerment of the rural people in the development of their sources of livelihood. In addition, sustainable agriculture conserves and enhances the natural land and water resource base as well as the environment as a whole. It is a farming approach that does not only ensure food security for the nation but also aims to mitigate the impacts of climate change and reduction of adverse impacts of agriculture on the environment (FAO, 2008; Biello, 2011). Aligned to the sustainable agriculture paradigm is the WOCAT (World Overview of Conservation Approaches and Technologies) Sustainable Land Management (SLM) framework which seeks to maintain and enhance productive capacity of soil through prevention or reduction of soil erosion, conservation of soil moisture and improvement of soil fertility (Linger *et. al.,* 1999*).* Several farming systems fall under the category of sustainable or climate smart agriculture but conservation agriculture CA has gained popularity especially on the American continent where it is often touted as an ideal system for continued crop production to support the increasing world population as well as for reduction of cultivation costs, improvement of human health and an increase in land degradation under adverse climatic conditions (Singh *et al.,* 2011; ICARDA, 2012).

Conservation agriculture encompasses a mix of agronomic practices all essential for soil and moisture conservation as well as building and maintenance of stable soil structure and sustainable crop production (Dumanski *et al.*, 2006; FAO, 2008). Paramount to conservation agriculture, as opposed to conventional farming (CF), is the zero or no tillage principle aimed at achieving minimum soil disturbance (Derpsch and Friederich, 2010; Landers, 2001). Besides zero tillage, other main features of conservation agriculture include permanent retention of crop residue (soil cover) as well as diversified cropping patterns (intercropping) and crop rotation (FAO, 2011a; Hobbs *et al.,* 2008). Despite its different meanings in dissimilar contexts of application (Nkala, *et al.,* 2011; Mlipha, 2004), for purposes of this study CA is regarded as the broad spectrum of farming techniques which put emphasis on zero or minimum tillage and adheres to fundamental farming techniques such as maintenance of permanent soil cover, intercropping and crop rotation (Mlipha, 2010). Specifically, the common CA practices introduced in Swaziland include zero tillage and direct seeding, ripping, tied ridges, basins to name but a few (SADC/ACT, 2009). In this research zero or no tillage was treated as an integral component of CA.

Previous studies indicate that adoption of CA is significant on the American continent accounting for 96% of total world acreage under the system (Derpsch, 2005a). Outside the American continent, only Australia is the major adopter of the system accounting for 2% of the global adoption rate (Derpsch, 2005b). Adoption rates are exceptionally low in Europe, Asia and Africa all accounting for 2% of the world's cultivated land under the system. The global adoption status of conservation agriculture portrays very little details about the pattern of adoption of the system especially providing clear and detailed profiles of the farmers readily practicing the system. Hence, there is the assumption that in the American continent the system was adopted mainly by large-scale commercial farmers (Landers, 1999). Yet reality is that a large number of small scale farmers practice the system in Brazil, the second largest adopter of the system in the world behind the USA (Derpsch, 2005b). Moreover, there are few details about the extent of adoption in terms of the proportion of land farmers dedicate to practicing conservation agriculture. Such details are crucial to inform national programmes formulated to facilitate the adoption of conservation among the local farmers.

Current initiatives indicate that CA in sub-Saharan Africa, with the exception of South Africa, is targeted at the small scale and resource poor subsistence farmers in areas prone to land degradation and drought (FAO, 2000). With the exception of Australia, information on the adoption of the system outside the American continent is lacking. Africa, Europe and Asia are part of the 2% adoption rate which gives very little meaning to the actual rate of adoption in these continents, not to mention in the individual countries. Moreover, it must be appreciated that the system is making gradual but significant inroads into Africa. South Africa is rapidly taking the centre stage in the adoption of CA having as early as the 1990s realised the threats of wind erosion which at that time affected about 2.5 million hectares of her grain producing land (Fowler, 1999). In Zimbabwe, only 1% of small scale farmers adopted the system compared to between 5% and 10% of large scale commercial farmers (FAO, 2008). Adoption details from other countries are not readily available except scanty estimates, hence the need to undertake country-based studies to ascertain the adoption status of conservation agriculture in African countries south of the Sahara.

The high adoption level in the American countries is attributed mainly to availability of information about the system and contribution of awareness raising campaigns (CGIAR, 2011). For instance, appropriate knowledge was availed to American farmers through research and development (Derpsch, 2005; CGIAR, 2011). Published research findings provided local and practical information to farmers and agricultural extension officers as well as a consistent and positive message about the system nationally. Appropriate information and awareness raising campaigns proved invaluable in changing attitudes among farmers. In Latin America aggressive farmer-to-farmer extension and campaigns were conducted through support of established no-tillage farmers' clubs and associations (Derpsch, 2005b). Similar clubs are emerging in Africa such as the African Conservation Tillage Network (ACT) which held its first conservation agriculture congress in 2014. Farmers' clubs proved crucial in the introduction of CA in Latin America as adoption rates were significantly higher among farmers organized in groups (van Lynden, *et. al.,* 2004).

Other factors facilitating adoption of conservation agriculture include prevalence of basic CA practices in the traditional framing systems. Latin American farmers had a long history of using cover crops (soil cover) as well as intercropping and crop rotation to control weeds and some pests. These farming practices, inherent in CA, presented familiarity of the system to the farmers and based on this familiarity they embraced the system (Sorrenson *et al.,* 1998). Traditional farming practices among small-scale subsistence in most African countries include some basic CA principles such as intercropping and minimum tillage. Lado *et al.* (2005) established that subsistence farmers in Swaziland practice intercropping more than mono-cropping despite pressure from exposure and training on conventional farming (CF) practices that put emphasis on mono-cropping. These traditional farming practices could enhance the adoption of CA among the local farmers.

Moreover, the higher adoption level especially in Latin American countries was attributed to the need for farmers to be competitive in the local and global market. Farmers in most developing countries do not receive subsidies for governments and to survive they need to be competitive in the global market. Therefore, adoption of alternative and cost effective farming techniques is imperative. The no-tillage and other aspects of CA reduce the cost of farming tremendously (savings on labour, fuel and time) and allow the farmers to cultivate large pieces of land at relatively low costs (Williams, 2008; Sorrenson, 1997). CA presents itself as highly suitable for the resource poor African subsistence farmers as well as the growing number of women farmers as crop cultivation is progressively becoming their responsibility.

The advantages and benefits accruing from CA are regarded as the biggest motivating factor for adoption of the system. Generally, crop yields under CA are either equal or higher than in CF (FAO, undated). However, compelling benefits of the system accrue over a longer period of time of practice (FAO, 2005). Crop yields are actually lower and production costs higher in the first few years of adoption (FAO, undated). The system also has lower labour requirements (FAO, 2005). Globally, an 86% reduction in labour costs for land preparation was observed while farmers in Indonesia benefited from 65% savings in land preparation costs after adoption of CA (FAO, 2005; FAO, undated). Just like in the case of yields, labour costs are higher at earlier stages of adoption of CA and they subsequently decrease with increase of the number of years of practice of the system. With the exception of labour and fuel costs, farm inputs are expected to be similar between CA and CF yet this is not the case (Mlipha, 2010). Correct application of CA must result in less use of inorganic fertilizers, pesticides and herbicides. Retention of crop residue increases organic matter content in the soils and improves general soil nutrient content or fertility while discouraging growth of weeds and breeding of some pests. The other benefit of CA is the savings on equipment and machinery. Local demonstrations reveal that very few farm operations requiring machinery are undertaken in CA, hence farmers need less machinery (Mlipha, 2010). The major benefit of CA is its contribution to the protection of the environment (Mlamba, 2010). The retention of crop residue provides the soil with permanent cover to prevent loss of soil nutrients and particles through run-off (soil erosion). Moreover, the system also ameliorates levels of some causes of climate change especially the deposition of greenhouse gases to the atmosphere (Mlipha, 2010). Assessments indicate that agriculture offsets about 40% of the estimated increase in CO_2 emissions to the atmosphere (FAO, 2005). The carbon credit payment system for farmers practicing conservation agriculture is receiving serious consideration and could result in financial gains to the farmers (Robbins, 2004).

Over the years CA appears to be a viable farming system in all kinds of environments and this element bodes well with the attempt to introduce the system in the drought prone areas of Swaziland where agricultural production and productivity has decreased substantially (SEA, 2000). With the adoption of CA, drought and poor soil fertility would seize to be limiting factors to crop cultivation as it is the case with conventional farming. Conservation agriculture has demonstrated the possibility of pursuit of productive agriculture activities even in the prevailing farming difficulties posed by climate change.

1.2 THE NATIONAL CONTEXT OF CONSERVATION AGRICULTURE

The Kingdom of Swaziland has a population of about 1.02 million people and increasing at a rate of about 2% per year (CSO, 2007) though this rate tended to decline over the years to about 0.9% (Government of Swaziland, 2012) due mainly to impacts of diseases associated with HIV/AIDS. The total land area of the country is about 17, 360 km^2 yet only 15-20% of the land is suitable for cultivation (Bruil *et. al*., 2014). It must be pointed out that the agricultural sector, particularly on SNL directly supports the livelihoods of more than 70% of the Swazi population for whom 60% of their income is derived from crop cultivation and rearing of livestock (Ministry of Economic Planning and Development, 2012; SEA, 2014). Moreover, agriculture contributes about 10% to national Gross Domestic Product (GDP), however it is important to note that about 60% of the country's manufacturing products are based on the processing of agricultural raw materials (Ministry of Economic Planning and Development, 2013). Agriculture is also the main source of employment which makes the sector essential for pro-poor economic growth. Despite an increasing urbanization rate of above 1.5%, the country's poorest households reside in the rural, thus rain fed smallholder agriculture on Swazi Nation Land remains essential for supporting livelihoods of the Swazi people and lift them out of poverty and hunger (Ministry of Economic Planning and Development, 2012).

Swaziland commands two agriculture production contexts: the Swazi Nation Land (SNL) defined as land held in trust for the Swazi nation by the *Ingwenyama,* His Majesty the king of Swaziland and there is communal ownership of land. On the other hand is Title Deed Land (TDL) where there is private ownership of land and production of crops and livestock is mainly for commercial purposes. Agriculture on the SNL is the primary concern of this study and the focus is on crop cultivation not rearing of livestock. Cultivation of crops on SNL is mainly for subsistence purposes and involves CF practices such as soil tillage and removal of crop residue either through burning or as winter fodder for livestock. Crop cultivation is practiced mainly under rain fed conditions with small proportion of farmers using irrigation. Agriculture is practiced on small landholdings with average size of 0.5ha comprising of a number of contiguous plots, called fields (*emasimi)* located within or outside the boundaries of the dispersed rural homesteads (Government of Swaziland, 2002). Soil tillage is traditionally practiced to create a "good" seedbed for planting as well as eradication of crop diseases and weeds associated with the previous crop. The SNL constitutes most of the country's cropland but contributed a mere 1.3% of the GDP (Central Statistical Office of Swaziland, 2001). Crop yields and general productivity per hectare in this agricultural sector has been low at around 1.0 tonnes per hectare for quite a long time as farming is characterised by being under rain fed conditions with low levels of capital inputs and technology use (Central bank of Swaziland, 2011). Farming on SNL, therefore, remains vulnerable to negative impacts of climate change and poor investments on crop production and land management (Central Bank of Swaziland, 2014). Unlike in South Africa where commercial agriculture is increasingly using CA techniques, in Swaziland farming in TDL is still rely predominantly on conventional farming techniques except in the large commercial plantation where minimum tillage has been adopted.

Adoption of new farming techniques is led by the local commercial farming sector which sets the example for the small scale farming sector to follow. The large scale commercial farming sector in Swaziland is therefore challenged to assume a leadership role in the adoption and practice of CA which currently is not the case.

The farmers are mainly heads of homesteads that cultivate crops and raise livestock simultaneously as traditional sources of livelihood and cultural heritage. It must be mentioned that very few farmers on SNL have formal education and their farming practices are informed mainly by information inherited from their forefathers. Hence farming records, pertaining to expenditure on inputs, yields and income derived from sale of crops are not kept. When it comes to yields, instead of keeping records memorize crop performance on annual basis and aim at obtaining better crop quality than previous years. This makes research and planning for agricultural development difficult. To be able to help farmers keep farming records the current literacy rate of about 40% of the farmers needs to be improved. The situation is to the contrary in the TDL where the farmers are educated with literacy rates above the national average of 89%. Farming on the TDL is predominantly for commercial purposes. Despite occupying a relatively smaller area of the national cropland compared to the SNL it accounts for a significant contribution to the GDP with a massive contribution coming from sugarcane farming (Central Bank of Swaziland, 2014; World Fact Book, 2005).

Therefore, since independence in 1968 the government of Swaziland took a keen interest in the development of the agricultural sector. Several policy and programme approaches were undertaken towards the development of agriculture especially smallholder agriculture on SNL areas. The 1968 Agricultural Policy was promulgated to provide a framework for strategies aimed at achieving food self-sufficiency through increased production of maize by farmers on SNL areas (OPM, 1997; UN, 2000). One of the earliest strategies to improve the smallholder agricultural sector included the implementation of the Rural Development Area Programme (RDAP) in the 1970s. The aim was to achieve food self-sufficiency and bring SNL farmers to commercial or semi-commercial level through the use of yield increasing inputs and extension services. The RDAP, however, failed to increase production mainly due to the fact that the incentives were inadequate for the risk and labour involved (Government of Swaziland, 1997). Technologies such as hybrid maize and fertilizer use were promoted and readily accepted by the majority of SNL farmers, but the main objective of the SNL farmer was to produce household requirements with reduced inputs of labour.

A policy shift from food self-sufficiency to food security was inevitable after the realisation that sufficiency did not necessarily mean a guarantee against hunger and malnutrition. The National

Development Strategy (NDS) of the 1990s reflected that policy shift as its major thrust was assisting farmers achieve basic food security and increased crop productivity through diversification and commercialization (Government of Swaziland, 1997). Maximization of real incomes through employment and income generation from agriculture was viewed as a conduit for ensuring accessibility to food supply by every Swazi (Government of Swaziland, 1997; UN, 2000; Smith, 2003). The establishment of government entities such as the National Maize Cooperation (NMC) and National Marketing Board (NAMBoard) was crucial for the development of maize and vegetables production in the country.

The period after the 1980s brought about many challenges to the smallholder agriculture sector on SNL which resulted in decline in agricultural production particularly maize. The crippling droughts of the early 1980s became a persistent feature indicating changes in the climatic outlook of the country since then to the present. To date climate change (and variability) is evident in Swaziland in many forms, including hydrological disasters (droughts and storms), changes in rainfall regime, and extreme weather conditions (Manyatsi *et al.*, 2010). Maize, the staple crop for the Swazi people, experienced a production decrease of about 70% since 1995 and the maize yields, cultivation area as well as productivity per hectare became variable with a downward trend after 2000 (Table 1.1) (Smith, 2003; FAO/WFP, 2008; Central Bank of Swaziland, 2011). In the 2012/13 farming season there was no significant improvement as productivity remained at 1.3 tonnes per hectare while slight increases were in the area under maize cultivation by 61 hectares and maize yield (82,000 metric tonnes) (Central Bank of Swaziland, 2014). The decline in maize production, that left 20% of the population experiencing food insecurity, was attributed to the prolonged drought as noted above while soil erosion and mono-cropping of maize were identified as major causes of agricultural failure in the country (FANRPAN, 2014; Smith, 2003; Sargent, 2003; Calegari, 2003). Nationally only 4% of homesteads produced enough food and sell surplus while 56% do not have enough for consumption while the number of homesteads who have enough to eat has dropped from 9% in 1992 to 4% in 2002. A majority of homesteads that never have enough to eat are found in Lubombo region (62%) where the study area is located (62%) while the average for the other regions is 55% (Ministry of Economic Planning and Development, 2007).

Table 1.1 Maize production on SNL (2000 – 2010)

Area (ha)	Farming seasons									
	00/01	**01/02**	**02/03**	**03/04**	**04/05**	**05/06**	**06/07**	**07/08**	**08/09**	**09/10**
Area ha (‘000)	69	58	68	68	54	56	47	47	60	52
Yield (000 mt)	113	83	68	69	68	75	67	26	60	71
Yield/Ha	1.6	1.4	1.0	1.0	1.3	1.4	1.4	0.6	1.0	1.4

Data obtained from FAO/WFP, 2008; Central Bank of Swaziland, 2011

The challenges posed by high prevalence of HIV/AIDS, which have been looming for a long time, have now reached pandemic levels with infection rates of between 20 and 25% among the productive population of 20 years and above (Central Statistical Office, 2008; Ministry of Health, 2010). A fundamental impact of HIV/AIDS is death and morbidity which have adverse implications on labour available for agriculture. The HIV/AIDS situation indicates a national loss of human and financial capital crucial for agricultural production in the rural areas resulting in the country's difficulty to achieve food security.

Despite the HIV/AIDS prevalence the population of Swaziland is still growing rapidly particularly in the rural areas. Government of Swaziland (1997) attributed the prevailing food insecurity situation at household level on the high population growth rate. Land fragmentation is now a problem due to an attempt to satisfy the ever increasing demand for land. Extension of farming to marginal land as well as continued practice of conventional farming techniques in the absence of sound management strategies has resulted in decline of soil productivity due to loss of soil moisture, nutrients and soil erosion. Consequently, only about 25% of arable land is available for crop farming on SNL areas as the remainder is under various stages of degradation (Bruil *et.al.*, 2014). The poor subsistence farmers Households lack funds to acquire the costly farm inputs such as fertilizers, hybrid seed, chemicals and farm implements. The farmers on SNL also limited access to equipment for soil tillage and general cultivation. The decimation of the livestock during the drought created shortage of animal traction while the number of tractors available for hire are either inadequate to meet the demand or too expensive to be afforded by the poor farmers on SNL.

Meeting food and income demands for the growing Swazi population is already a formidable challenge for the agriculture sector and the situation is compounded by climate change. The apparent pattern of erratic and late rains in the last several years required a speedier adoption of appropriate agricultural strategies and uptake of appropriate farming systems and techniques to save about 407 000 people from experiencing food insecurity. The FAO (2002) advocated for the adoption of viable agricultural systems that increase productivity while reducing pollution and resource degradation. The National Agriculture Summit commissioned by the Government of Swaziland in 2007 can be viewed as one of the initiatives intended to achieve what was advocated by the FAO.. Various options to address smallholder agricultural production were acquired from the summit and were articulated in the Swaziland Agricultural Development Programme (SADP). One of the key options was the introduction, adoption and practice of farming systems and techniques that would withstand the adverse impacts of climate change (FAO, 2011b). Such farming systems or techniques are referred to as Climate Smart Agriculture (CSA) and they include mainly conservation agriculture and other techniques such as special irrigation techniques, permaculture and others. The government of Swaziland, with its collaborating partners, introduced CA at the beginning of the 2000 decade without a proper analysis of prospects and challenges of its introduction and adoption in Swaziland especially among smallholder farmers. To a large extent, the introduction of CA in Swaziland, as described below, relied on lessons and experiences derived from other countries in the African continent and outside. Moreover, the introduction of CA lacked local empirical information and details about its performance in terms of productivity and retention of soil moisture content and nutrients. Hence, the study made an attempt to present the prospects and challenges of introduction and adoption of CA as well as estimate its performance in terms of retention soil moisture and improvement of soil nutrient content.

1.3 INTRODUCTION OF CONSERVATION AGRICULTURE IN SWAZILAND

Conservation agriculture is by far the most common or popular climate smart agriculture system being promoted in the country. Conservation agriculture was successfully introduced in other parts of the developing world and has demonstrated its potential to transform production and productivity in the local smallholder agriculture. Brazil and Zambia provide examples of countries where successful adoption of CA techniques had a significant in impact on the development of the smallholder agricultural sector. Conservation agriculture, especially the zero tillage and retention of crop residue principles, is renowned for retention of soil moisture in dry climatic conditions as well as improvement of soil fertility. Moreover, the zero or minimum tillage inherent in the system results in reduced farming costs especially reduction in labour and inputs costs while increase in crop production, productivity and diversity is realized.

Conservation agriculture was introduced in Swaziland by the government in collaboration with several international agencies mainly the Food and Agriculture Organization (FAO), Cooperation for the Development of Emerging Countries (COSPE), Africa Cooperative Action Trust (ACAT) and World Vision to name but a few. Introduction of the system was supported by the FAO's *Awareness Creation of Conservation Agriculture Project* which ran for 20 months from 2003 to 2005. The project was aimed at promoting the adoption of conservation agriculture by the subsistence farmers in Swaziland (FAO, 2000). It must be noted that the initial thrust of the project facilitating the introduction of CA in the country was to ensure food security through promotion of cultivation of traditional crops. The cultivation of traditional crops does not in any way mean adoption of CA. The project facilitated cultivation of traditional crops as a medium to achieve food security based on the notion that traditional crops are resilient to adverse climatic conditions and may thrive better from the benefits of adoption of CA which include retention of soil moisture, among others. However, the status of crop cultivation and criteria used by farmers to select crops for cultivation was never established before the implementation of the project. It is on that basis that the research on the selection and cultivation of crops was one of the components of the study intended mainly to yield information on crop cultivation and status, crop selection and patterns of crop cultivation.

Several activities were undertaken during project implementation including the establishment of four pilot areas in all four administrative regions of the country including Motjane in Hhohho, Luve in Manzini, KaMbhoke in Shiselweni and Shewula in Lubombo. All the pilot areas were equipped with testing and validation plots for purposes of demonstration in the training of farmers in CA techniques. In addition, several workshops and demonstration sessions were conducted during training of farmers and extension officers on the principles of the system. A workshop worth mentioning was titled *Use of Indigenous Species for Sustainable Development towards Food Security* which was intended to promote cultivation of indigenous crops which were anticipated to be able to withstand the prevailing dry conditions among their advantages. The activities were also intended to stimulate interest among farmers and facilitate adoption of the system. The main conservation agriculture principles promoted and practiced in Swaziland are zero tillage, retention of crop residue and basin seeding/planting (Mlipha, 2010; SADC/ACT, 2009).

1.4 RATIONALE OF THE STUDY

The biggest concern in Swaziland and other countries in sub-Sahara Africa is the prospect of the farmers to adopt the system. The daunting obstacle to the adoption of conservation agriculture is the prevailing mind-set not only among the farmers but also researchers and agricultural extension officers (FAO, undated). The mind-set is still rooted on and influenced by conventional farming techniques which are reinforced by current local curricula in lower and higher education. Conservation agriculture requires a new way of thinking among farmers as well as existence of technical, agronomic and economic benefits to positively influence farmers to adopt the system (FAO, 2004). The question that requires urgent response has to do with the challenges and prospects of the local smallholder farmers adopting conservation agriculture. Identification of the challenges at the onset helps the government and collaborating partners to address them and enhance the chances of adoption of the system. On the other hand the study of the prospects helps in reinforcing them particularly as success factors for adoption of the system.

Conservation agriculture was introduced in Swaziland without any systematic creation of baseline data or information to help in the monitoring and evaluation of the effectiveness of the campaigns facilitating the adoption of the system in the country. This study intends to make a contribution by providing the basic baseline information and understanding of the recently introduced farming system. The FAO's project on raising awareness of conservation agriculture among smallholder farmers in Swaziland is based on promotion of cultivation of indigenous crops as a medium of achieving household food security. To ascertain the effectiveness of the implementation of the project information on the status of cultivation of crops among the farmers is required. However, there is currently no authoritative information available on the various types of crops to ascertain the level of cultivation of indigenous crops. It is, therefore, important to establish the status of crop cultivation in terms of types of crops being cultivated, their selected criteria as well as the cropping pattern. Such information would also help to establish whether there will be a successful transition back to the cultivation of indigenous crops particularly in the era of hybrid crops. Knowing the cropping pattern would be of significance especially to have an inkling of farmers' readiness to embrace intercropping and crop rotation being techniques concomitant with conservation agriculture.

The positive impacts of CA would be realized if it is adopted by a significant proportion of the smallholder farmers of SNL. For this to happen CA, as farming system, must receive positive perceptions and attitudes from the farmers. Therefore, it is important to ascertain the status of the adoption of the system since its introduction in 2000. Currently, there is uncertainty of the proportion of farmers practicing the system as well as the significant proportion of the farmers adopting the technique for it to have a significant impact on the rural people's livelihoods. At the moment information is lacking on the farmers' perceptions and attitudes towards CA. There is also uncertainty on farmers' willingness to adopt and practice the system.

Availability of information about CA was critical for its adoption by farmers in Latin American countries (Dumanski *et al.*, 2006). It must be pointed out that the lack of information on local examples and experiences of practice of CA is one of the bottlenecks to its adoption among the local farmers (Dlamini & Masuku, 2011). Ground breaking studies, such as this one, would be incomplete without contributing information on the performance of the system when practiced by the local farmers. The study opted to contribute information on the influence of CA on soil fertility focusing on basic soil parameters very familiar to farmers such as pH, moisture, organic matter and nutrient content. The objectives of the study presented below gives specific actions to be undertaken and accomplished related to the rationale of the study.

1.5 PROBLEM STATEMENT

Conservation agriculture was introduced in Swaziland in 2000 through a FAO supported project. The project lasted for about five years and it sought to facilitate the adoption of the system by small scale subsistence farmers on the Swazi Nation Land. The research problem centres around some factors described below including the fact that conservation agriculture was introduced without any baseline information pertaining to its prospects for success as well as challenges that may constrain its adoption. It is essential that factors that may enhance the adoption of CA be noted and enhanced while identified challenges are addressed to facilitate the adoption and practice of the system in the country. Moreover, as observed above, the FAO CA Project emphasized on, among other practices, the cultivation of indigenous food crops to address food security in rural areas. However, this was done without establishing the prevailing status of cultivation of crops as well as criteria farmers use to select crops for cultivation. Such information is significant especially to understand the types of crops likely to be preferred by the farmers, how they select the crops to be cultivated as well as establish their mind-set and preparedness to adopt indigenous crops. In the decade since the introduction of CA it remains to be ascertained the extent to which the system has been adopted by the farmers in the country. To date, there is no empirical data demonstrating the adoption status of CA among the local farmers. It is important that research document the level of adoption of CA and the attitudes of subsistence farmers towards the system. It is also important to ascertain the influence and the role of the FAO's awareness creation project among the subsistence farmers.

The introduction of CA in Swaziland was done against the backdrop of insufficient local information resources about the system. Information on CA was derived from publications based on studies conducted in other regions of the world particularly Latin America. It must be noted that availability of information materials with local content was key in the adoption of CA in Latin America (Derpsch, 2005b). The limited literature reports on CA are some of the challenges experienced in the introduction of the system in Swaziland. Dlamini & Masuku

(2011) made a comparative analysis of farming costs and crop yields on convention agriculture and conventional farming (CF) plots. However, this study is one of very few research projects conducted in the country on the performance of CA in comparison to CF. Hence, existing literature on CA in the country suffers severe deficiency of empirical data on many aspects of the system (including benefits) in terms of yields and savings on labour and farming inputs, to name but a few. The problem of unavailability of empirical data is exacerbated by the fact that local subsistence farmers generally do not keep any records of their farming activities thus denying researchers access to valuable data. The problem of lack of data is quite evident in the study reported in Chapter 2. Clearly, more research projects on CA are critical to generate data to support the efforts towards the adoption of the system in the country. It was, therefore, important for this study to acquire empirical data on the performance of CA in the maintenance and improvement of soil water retention, organic matter content and soil nutrient.

Critical research questions emanating from the problem statement above and reflected by the objectives below are:

- What are the prospects and challenges of adoption of conservation agriculture by the subsistence farmers in Swaziland?
- What is the status crop cultivation, cropping patterns as well as factors guiding selection of crops for cultivation by subsistence farmers
- What is the level and pattern of adoption of conservation agriculture among the subsistence farmers at Shewula
- Do soil cover and accumulation of crop residue inherent in CA have influence on soil moisture and organic matter content?
- Are there differences in organic matter and nutrient content between soils under conservation agriculture and those under conventional farming?

1.6 SPECIFIC OBJECTIVES OF THE STUDY

The study analyses the extent of adoption of CA and attempts to document baseline information on various aspects of the introduction of the system in Swaziland using Shewula as a case study. The description of Shewula and rationale for its selection as a case study is presented below. The study is divided into five separate but related components presented as stand-alone but related papers or chapters in the report. Hence the chapters below especially chapters 2, 3, 4, 5 and 6 have inevitable periodic duplications particularly in the introductions, description of study area and methods. The five study components undertaken sought to achieve the following objectives:

1.6.1 ***To investigate the prospects and challenges of adoption conservation agriculture by the local subsistence farmers***. This objective intended to highlight prevailing opportunities for adoption of CA as well as dilemmas of introduction of the system that may potentially curtail its successful use by the local subsistence farmers.

1.6.2 ***To establish the status of crop cultivation, cropping patterns and factors guiding selection of crops for cultivation by subsistence farmers at Shewula.*** This objective sought to present the status of crop cultivation especially the types of crops cultivated by the farmers as well as their crop selection criteria and prevailing patterns of crop cultivation.

1.6.3 ***To ascertain the level and pattern of adoption of conservation agriculture at Shewula***. This objective sought to estimate the level and pattern of CA adoption as well as factors facilitating and constraining its adoption by the farmers at Shewula.

1.6.4 ***To assess the extent of soil cover and accumulation of crop residue and their influence on soil moisture and organic matter content***. It is known that CA adoption is determined by successful practice of the system's basic techniques. The study paid particular attention to zero tillage and retention of crop residue (soil cover) because they contribute to retention of soil moisture and improvement of soil nutrient content. For these to be realized, soil cover must be a minimum of 30% of the plot and there must a significant accumulation of stubble. The objective therefore sought to estimate the average soil cover and residue accumulation by the farmers and relate these to the soil moisture and organic matter content.

1.6.5 ***To conduct a comparative analysis of organic matter and nutrient content in soils under conservation agriculture and conventional farming***. This objective sought to demonstrate the performance and effectiveness of CA to improve and maintain soil fertility. This was mainly intended to provide local empirical information on the performance of CA which was missing yet critical for the promotion of adoption of the system among smallholder farmers in the country.

1.7 GENERAL DESCRIPTION OF THE STUDY AREA

1.7.1 Brief description of Swaziland

The study was conducted at Shewula a rural settlement in Swaziland. Swaziland is one of the smallest countries in Africa measuring about 17 000 km^2. The country is located south-east of the African continent at approximately 26^o 30' south and 31^o 30' east. Swaziland is completely surrounded by South Africa in north, west and south while in the east the country shares a border with Mozambique.

Swaziland is conventionally divided into four ecological zones or physiographic regions run parallel to one another on a north-south projection. The ecological zones include the Highveld, Middleveld, Lowveld and the Lubombo plateau (Figure 1.1). Shewula is located in the northern part of the Lubombo Plateau. The ecological zones are defined mainly based on altitude but also landform, geology, soil, temperature and vegetation. The Middleveld is often subdivided into Upper and Lower Middleveld zones. The Lowveld is also subdivided into the West and East Lowveld zones giving a total of 6 detailed ecological zones. The climate of the country differs according to the ecological zones and varies from subtropical in the Highveld to near temperate in the Lowveld. The country has a single rainy season that spans between September and March with higher amounts of rainfall received in the hot summer months of November, December and January. Below is a detailed description of the country based on the four ecological zones.
The Highveld is situated in the West and it is mainly mountainous. The underlying rock formation is predominantly the coarse-grained granite (Mswati group) and the Lochiel coarse to fine grained granites. The region receives a normal annual rainfall of about 1 000mm to 1 200mm. Only 10% of land in the Highveld is suitable for cropping. A significant portion is planted with mainly eucalyptus and wattle.

The Middleveld is mainly characterised by a rolling terrain dominated by the Ngwane gneiss and the coarse to medium grained granite. The region receives a normal annual of about 800mm to 900mm. The Middleveld is the main area of rain fed agriculture. The upper Middleveld receives more rainfall than the lower Middleveld owing to its slightly higher elevation.

The Lowveld is more eastwards before the Lubombo Plateau. The Lowveld is a gentle sloping bushy terrain resting on top of a thick belt of the Sabie basalt bordered by Ecca group of sandstones, clay stones and coal. The Lowveld experiences hot summer temperatures while the rainfall is normally low and unreliable, seldom exceeds 700mm per year owing to the rain shadow effect of the Lubombo mountain range. The soils of the Lowveld are highly productive the only limiting factor to agriculture is the persistent drought.

The Lubombo Plateau is more to the east and is dominated by the Lubombo Rhyolites with quartz. The region is characterised by a gentle sloping plateau dipping eastwards towards Mozambique. The steep slopes are an impediment to agriculture as well as the shallow acidic soils. Agriculture is therefore concentrated on fertile soils lying along the small streams that emanate from and cut through the Plateau.

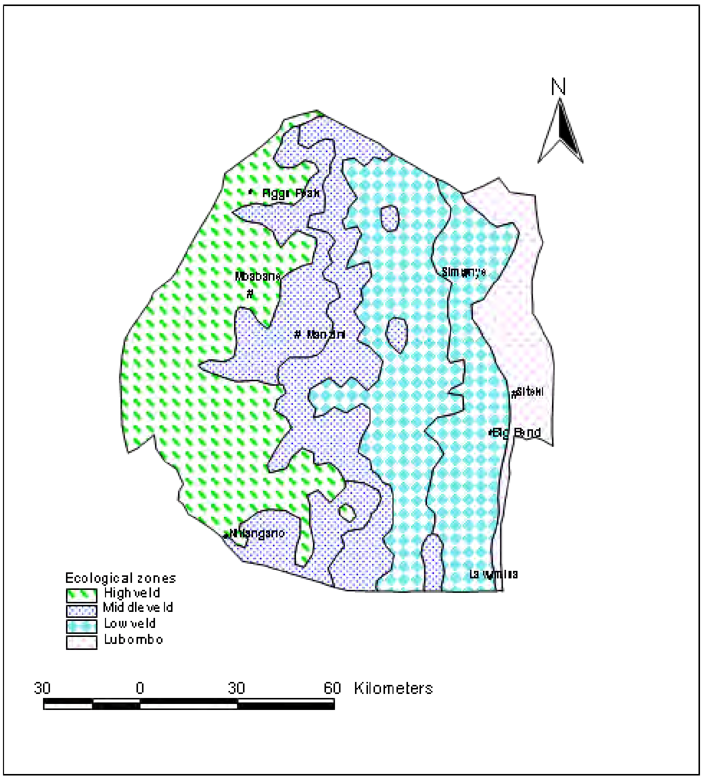

Figure 1.1 Physiographic regions in Swaziland (Ministry of Economic Planning (2012), Rio+20 National report)

The population of Swaziland has increased fourfold from 84 000 people in 1904 to slightly about 1.2 million people in 2005. About 70% of the people live in the rural areas. The Middleveld accounts for a higher percentage of the national population at 37% followed by the Lowveld at 30% and the Highveld at 28% of the national population. The Lubombo plateau accounts for a mere 5% of the national population. In recent times there has been significant migration into the Middleveld and Lowveld because of the job opportunities in the manufacturing industries in Manzini and the sugar plantations of Mhlume, Simunye and Big Bend. The population is predominantly young with about 40% of the population in 0 – 14 years categories and about more 50% in the 15 – 65 years category. Elderly people aged 65 years and above account for only 4% of the total population. The life expectancy which used to around 65 years before the HIV/AIDS impact has now gone down to 37 years among males and 34 years among females. Females have been found to be most vulnerable to HIV infection than males. The natural increase has also tumbled down from about 3.6% before the HIV/AIDS pandemic to current estimates of 0.9%. The national HIV prevalence is estimated to be slightly above 20% of the population. The national literacy rate is currently estimated at about 81.6% of the population 15 years and above. The literacy rate among males is slightly higher than the national rate at 82.6% of male population 15 years and above. Literacy rate among subsistence farmers is estimated at 40% and even lower among female farmers and heads of homesteads. Due to prevalent illiteracy the subsistence farmers rely on traditional methods of farming and do no keep records of yields as well as their expenditures and incomes. About 60% of Swazi population lives below the poverty line of one US dollar per day due to a number of factors including HIV/AIDS, the prevailing drought and unemployment.

Subsistence agriculture, undertaken under rain fed conditions, is the most dominant land use practiced by approximately 70% of the population. Irrigated commercial cropland covers only 119 km^2 which is about 6.7% of the total cropland (Government of Swaziland 1994). Climate change and variability is the biggest threat to agricultural development and it has been identified as the only realistic natural disaster the country experiences nowadays. Moreover, soil erosion ranks amongst the most important environment issues the country needs to address urgently as it has a potential of adversely affecting agriculture as the people's main source of livelihood. Other land uses including forest plantations in the Highveld and sugar-cane plantation in the Lowveld. Land is also set aside for industrial development especial in the period after 1980. The same period however witnessed the demise of the mining activity in the country.

1.7.2 General description of Shewula

This is a general description of Shewula and more detailed and specific description of the area is made in the subsequent chapters below. Shewula is a rural settlement situated in the north-eastern part of Swaziland at the border separating Swaziland and Mozambique (Figure 1.2). It is perched on top of the Lubombo plateau at approximately 300-600 metres above sea level with steep slopes on the west and gentle undulating plateau to the east and forests stretching along the Mbuluzi River. Shewula experiences a subtropical climate characterised by seasonal differences in temperatures and rainfall. Average winter temperatures are lower at approximately 10°C and rise to about 27°C in the summer season. Rainfall occurs in summer ranging between 550 and 850mm per annum. Further physiographic and other details about Shewula are presented at appropriate points later in the document.

Shewula comprises about 930 homesteads randomly dispersed along the Lubombo escarpment with shelters constructed mainly from grass thatch, wood and stones. The population of Shewula is estimated at about 10 000 people distributed within the 13 subareas as indicated in Figure 1.2 below. Shewula is located far from industries and the landscape is also mountainous for the development of agricultural plantations. For that reason the community depends mainly on subsistence agriculture and tourism. Maize, being the staple crop, is grown on a wide scale although yields are continuously declining due to the persistent drought, poor shallow soils, limited access to agricultural resources, lack of cattle (for animal traction) and tractors for hire. The problem of HIV/AIDS is also rife at Shewula and might be having some important impacts on agriculture. There are many orphaned and vulnerable children (OVC) at Shewula which has resulted in the construction of a school and feeding facility exclusive for them. COSPE, an Italian NGO, is currently assisting 620 OVCs with education and food supply. Moreover, many households in Shewula are now headed by women who besides providing care for their families they also have to run all farm operations. The importance of agriculture cannot be overemphasized, particularly as a basic source of food, adhering to the dietary requirements of those living with the HIV/AIDS.

Other crops cultivated at Shewula include sorghum, beans, *jugo* beans, and other traditional crops albeit on a small scale. Livestock farming is also practiced, but the livestock herds especially cattle and goats are relatively small. This is due to the fact that for a long time Shewula was in a foot and mouth disease quarantine area which imposed stringent measures for disposal of livestock. Moreover, the area was also subjected to sporadic cattle rustling during the Mozambican civil war resulting in fewer homesteads with cows. The problem of cattle rustling still persists and reduces the farmers' access to draught animal power especially for agricultural activities like soil tillage. Hence the introduction of CA is significant to the people of the Shewula chiefdom.

The community also practices a wide range of non-farm activities to augment proceeds from farming. The most important is the community's active participation in the tourism industry. The Shewula Mountain Camp is an important tourist attraction and income generation facility run by the community as a Trust. The Camp is a result of cooperation between the Shewula community and the Lubombo Conservancy which spreads over an area of about 60 000 hectares transcending Swaziland, Mozambique and South Africa.

Shewula was selected primarily for being one of the four pilot areas of the FAO's awareness creation of conservation agriculture project in Swaziland. At the time of the study Shewula was already at an advanced stage of introduction of the CA and therefore offered scenarios of practice of the system crucial for the study. The existence of the test and validation plots alongside on-going conventional agriculture offered a unique contrast of the farming systems ideal for comparative studies. Moreover, Shewula is situated at the border with Mozambique and this offers a unique blend of socio-cultural diversity which transcends into the agricultural practices. The cultivation of cassava is rife in Mozambique but the cultural interface between Swazis and Mozambicans at the border areas has manifested in the adoption of cassava, a drought resistant crop ideal for adaptation to climate change.

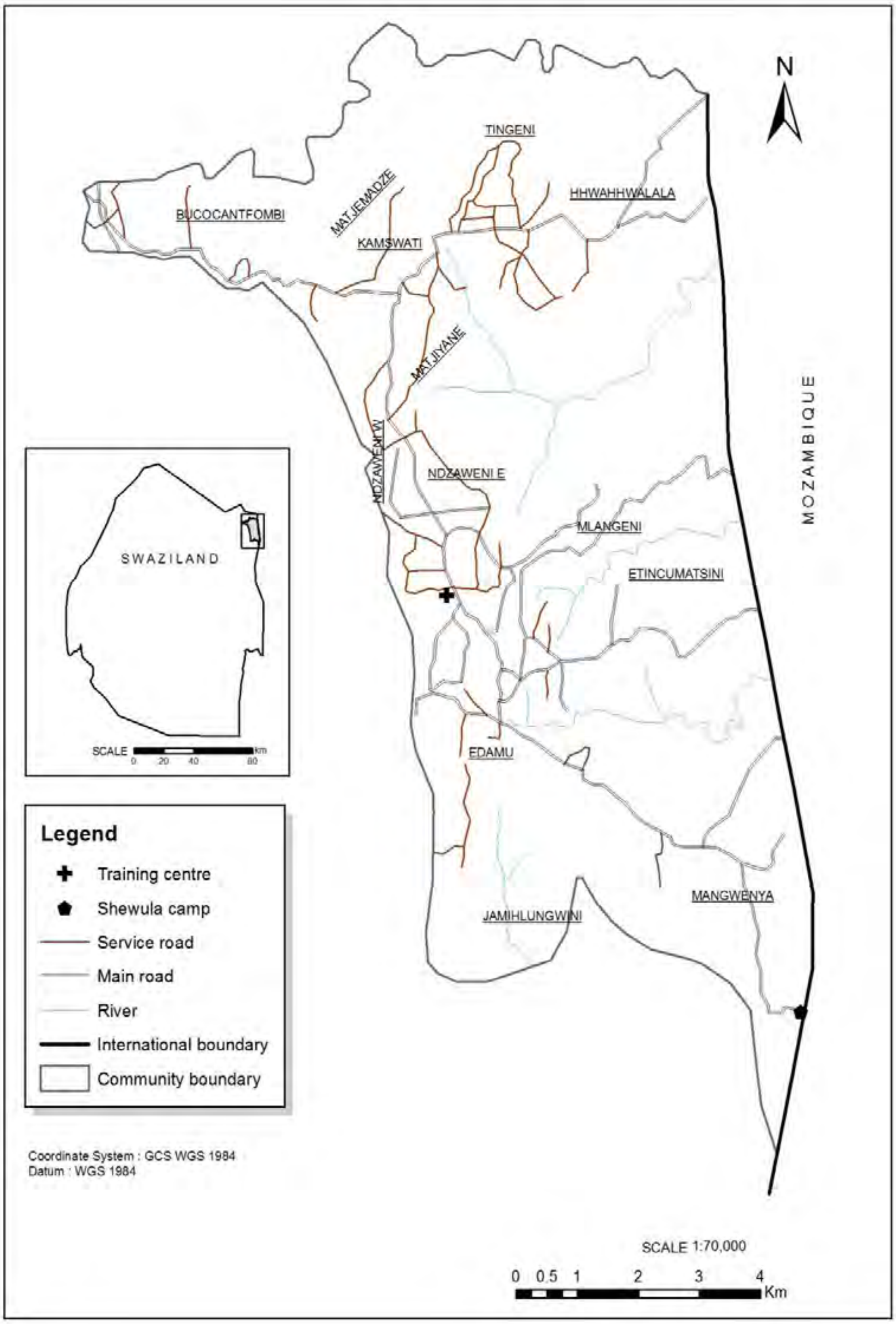

Figure 1.2 Map of the Shewula chiefdom indicating the various subareas

1.8 METHODOLOGICAL APPROACHES

The methodology of the study varies substantially with the various components of the study undertaken. The methodology includes desktop research (literature review), questionnaire (survey), key informant interviews, focus group discussions, field survey as well as soil sampling and analysis. In part, the methodological approach includes different data collection techniques and analysis to demonstrate the researcher's versatility and comfort with handling different research methods which is ideal for senior researchers in the discipline of Geography though not a requirement or prerequisite. The methodology is described in details in all the chapters below reflecting the various components of the study.

1.9 ORGANIZATION OF THE REPORT

The report constitutes seven chapters. The first is an introductory chapter that provides the global and national contexts of conservation agriculture while presenting the understanding the concept of conservation agriculture in Swaziland and in the study. The chapter also presents the rationale of the study as well as the theoretical basis of the study. Lastly, the chapter presents the environmental setting of the study including the description of Swaziland and Shewula where the study was conducted. The rationale of the selection of Shewula as study area is also stated. The rest of the chapters down to chapter 6 constitute independent (but related) and publishable research articles. There is inevitable repetition in the initial sections of the chapters that needs to be appreciated and tolerated as the chapters deal with the general subject and conducted in the same study area. Some repetition was unavoidable in sections such as the introduction and description of the study area however; the repetition was minimized by varying the information according to the different contexts of the studies being reported.

Chapter 2 has already been published (as a chapter) in a 2010 volume titled *Socio-economic Development and the Environment* edited by D.S. Tevera and J.I. Matondo. Chapter 2 discusses prospects and challenges of adoption of conservation agriculture by subsistence farmers in Swaziland. This non-empirical research relied mainly on the review of a variety of literature and internet publications. The chapter provides background information for the whole study especially about the understanding of the system and its introduction in Swaziland. However, the main focus of the chapter is on the discussion of factors facilitating the adoption of the system as well as those that may constrain its adoption. This then provided the basis for suggesting the prospects of the adoption of the system by the smallholder subsistence farmers in Swaziland. Chapters 3, 4, 5 and 6 are in the process of being prepared for publication in refereed journals in the SADC region and outside.

Chapter 3 presents the status of crop cultivation, cropping patterns and factors guiding the selection of crops by subsistence farmers at Shewula, Swaziland. This was mainly a survey mounted to provide baseline data on status of crop cultivation necessary for future assessment of the attempt to encourage cultivation of indigenous crops which was the major thrust of the project introducing conservation agriculture in the country. Chapter 4 is about the level and pattern of adoption of conservation agriculture at Shewula in Swaziland. This was also a survey that ascertained the adoption status of adoption of conservation agriculture and examined the demographic and spatial patterns of adoption of the system at Shewula. The chapter also presents the factors that motivated some of the farmers to adopt the system as well as those that impeded its adoption. Chapter 5 is about the influence of conservation agriculture on moisture and organic matter content in soil under cultivation at Shewula in Swaziland. The study focuses on measurement of the amount of soil cover and mass of crop residue in plots under conservation agriculture and those under conventional farming. Thereafter, analysis of soil samples was conducted to estimate the amount of water and organic matter content. This was done to establish the influence of conservation agriculture on soil moisture and organic matter content. Chapter 6 presents a comparative analysis of nutrient content in soils under conservation agriculture and conventional farming at Shewula in Swaziland. Sampling was conducted in CA and CF plots and the samples were tested for levels of soil pH as well as content organic matter and basic nutrients such as nitrogen (N), phosphorous (P) and potassium (K). This was intended to establish the influence of conservation agriculture, as the only factor distinguishing the two systems, on soil pH, organic matter and nutrient content.

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CHAPTER 2

THE PROSPECTS AND CHALLENGES OF ADOPTION OF CONSERVATION AGRICULTURE BY SUBSISTENCE FARMERS IN SWAZILAND

2.1 INTRODUCTION

In Swaziland conservation agriculture (CA) was introduced at the beginning of the 21st Millennium. Conservation agriculture is gaining positive recognition globally owing to its popularity and success in North America and South America where it is practiced by approximaely 47% and 39% of the farmers respectively (Derpsch, 2005a; Dumanski *et. al.,* 2006). In Africa, CA is practiced at a relatively small scale but there is a growing recognition of its significance derived from its success in other semi-arid parts of the world (FAO, 2006a; Nielsen, *et. al.,* 2005; FAO, 2000). For instance, the adoption rate of CA in Zambia and Zimbabwe was estimated at about 5% to 10% of the farmers, while in Ghana about 350 000 farmers practiced CA between 1990 and 2000 (Elwell, 1994; FAO, 2005b; Baudron *et. al.,* 2006). CA is understood differently in the various contexts where it is practiced (Mlipha, 2004). However, it is commonly viewed as the cultivation of crops without tillage of the soil, *i.e.* zero or minimum tillage (Landers, 2001; Derpsh, 2005a; Dumanski *et. al.,* 2006). Dumarski *et.al.* (2006:64) regards zero tillage as a "cornerstone of CA, and can be practiced in both large and small farming systems". Zero tillage (also termed no-tillage and direct drilling) allows for accummulation of crop residue to prevent direct splash of raindrops and soil erosion. Organic matter of the surface layers of zero tilled land increases, due to reduced erosion, increased yields resulting in more crop residue added to the soil surface and differences in the assimilation and decomposition of soil organic matter (Dumanski *et. al.,* 2006). Application of seed and fertilizers is directly into the stubble of the residue of the previous crops unlike in conventional farming where a seed bed is normally prepared through removal of residue and soil tillage. Soil tillage, owing to softening of soil and removal of crop residue, leaves the soil exposed to agents of erosion and evaporation.

Clearly, the views expounded above treat zero tillage as integral to conservation agricultural systems and it distinguishes CA from conventional farming (CF) systems which focus mainly on soil tillage (Dumanski *et. al.,* 2006; Derpsch, 1998 & 2005a; FAO, 2006a). However, in its broader scope, CA is not just zero tillage but a holistic farming system characterized by various farming technics, including zero tillage, with interactions among households, crops, and livestock which result in a sustainable agriculture system that meets the needs of farmers

(Hobbs, undated). The FAO, on its part, sees zero or minimum tillage and direct seeding as important elements constituting CA. In Swaziland, CA is viewed as a group or mix of farming techniques essential for soil and water conservation while building a stable structure for sustainable crop production and diversity (FAO, 2008). Moreover, there is emphasis on minimum soil disturbances through practice of zero tillage while adhering to other fundamental principles of CA which include permanent soil cover by crop residue and cultivation of a variety of crops through intercropping and rotation (FAO, 2011a; Hobbs *et. al.,* 2008).

2.2 THE RELEVANCE OF CONSERVATION AGRICULTURE IN SWAZILAND

Conservation Agriculture in Swaziland was introduced in 2000 against a backdrop of increasing food security concerns. Slightly more than 10% of the population experience food (maize) shortage amid continued national failure to achieve self-sufficiency in maize production and supply to people (Magagula *et. al.,* 2007; National Maize Corporation, 2010; Swaziland Vulnerability Assessment Committee, 2010; IRIN, 2012). Above 70% of the population depend on rain fed subsistence farming involving soil tillage and practiced exclusively on Swazi Nation Land (SNL). The SNL is communal land under traditional authority and occupied by indigenous people enjoying user rights without access to individual and legal title. Due to impacts of climate change, particularly the persistent drought, subsistence farming in Swaziland experiences continued crop failures resulting in shortages of maize, the staple crop of the Swazi nation (Riddell & Manyatsi, 2003; Smith, 2003; Sargent, 2003; Edje & Mavimbela, 2005; Manyatsi *et. al.,* 2010; World Vision Swaziland, 2010; Dlamini, *et. al., 2012*). The soil tillage aspect of subsistence farming exposed poor soils to elements of weather thus increasing the soil's susceptibility to erosion and loss of fertility (Russell, 1999). Poor soil fertility is widely accepted as a limiting factor to crop production among small scale farmers (Sanchez *et. al.,* 1997). The decline in food crop production is also precipitated by escalating poverty where a majority of farmers experience corresponding decline of incomes from farming while there is a constant increase in the costs of farm operations and inputs. There is also a shortage of labour, especially male labour, to undertake crucial and demanding farming activities. The shortage of labour is attributed to out migration to wage employment as well as impacts of the HIV/AIDS pandemic (FAO, 2006b; World Vision Swaziland, 2010). Current HIV/AIDS prevalence in the country is estimated above 30 % on average nationally (Central Statistical Office & Macro International Inc., 2008; Ministry of Health, 2010).

It was observed that Swaziland needed a change in its farming systems and accompanied by accelerated adoption of water harvesting techniques, otherwise redressing the prevailing food shortages and poverty would have been impossible (Singh, 1990; FAO, 2002; Phakathi, 2009). In 2000 the National Action Programme (NAP) to combat desertification recommended the adoption of farming systems efficient in utilization of land resources and sustainable in the production of crops (Swaziland Environment Authority, 2000). Moreover, studies also showed conditions under which small scale farming was conducted as critical and called for the adoption of CA as a system with potential to address current food shortages as well as soil erosion and vulnerability to climate change (Calegari, 2002; World Vision Swaziland, 2010).

Theoretically, the introduction and adoption of CA in Swaziland can be situated within the sustainable livelihoods and adaptation frameworks. The sustainable livelihoods framework is helpful in the analysis of rural livelihoods and particularly circumstances surrounding decline of agricultural production (Swift, 1989; Chambers, 1994; Ellis & Briggs, 2001). The sustainable livelihoods approach recognizes efforts of rural communities to pursue their own livelihoods as the approach is bottom-up, participatory and empowering to rural people (Carney, 1998; DFID, 1999). Livelihood is understood in this study as the way in which people pursue their basic livelihoods including their capabilities, assets used and activities undertaken (DFID, 1999; Ellis, 2000). As noted in chapter 1 above livelihoods have to be sustainable for them to be meaningful (Goldman, 1998; Ellis, 2000; Ellis & Briggs, 2001). The pertinent question addressed in the discourse, among others, is that of threats to sustainability of rural livelihoods and their mitigation strategies. The reference to shock and stress contexts in the sustainable livelihoods framework enhances ones appreciation of the underlying threats to sustainability of rural livelihoods necessitating change to other farming systems as mitigation strategy. Various biophysical and socio-economic threats to agriculture are noted including drought, soil erosion and decline of soil fertility, rural poverty, escalating costs of farm inputs, inadequate equipment and others (Conway & Barbier, 1990; Goldman, 1998). As noted above, a majority of the mentioned threats are prevalent in Swaziland and they formed the context necessitating the introduction of conservation agriculture.

The adaptation framework regards the mentioned biophysical and socio-economic threats to agriculture as triggers of society's systems, institutions and individuals capabilities that compel them to adapt to the changing adverse conditions threatening their existence (Smithers & Smit, 2009; Ericksen *et. al.,* 2011). Adaptation is often regarded as one of policy options to climate change influencing development practice (Tanner & Mitchell, 2008). Hence adoption of conservation agriculture denotes adjustment of farming systems to mitigate effects of threats such as drought and others to maximize on advantages that may be available (Eriksen *et. al.,* 2011). The adoption of CA somehow negates the modernization approaches to agriculture which are viewed as more ecologically and culturally disruptive (Toledo, 1990). It demonstrates a shift towards alternative systems that are cultural sensitive and ecologically sound (Alteri, 1981). Adaptation, according to the theory, may either be spontaneous or planned (Smithers & Smit, 2009). In Swaziland, the introduction of CA (especially zero tillage), as an adaptation strategy to climate change and other threats to agriculture, was planned. It was a deliberate government effort implemented through FAO the project RCP/SWA/2909 of 2000 on "awareness creation of conservation agriculture" (FAO, 2000).

2.3 CONSERVATION AGRICULTURE IN SWAZILAND

As noted above, the introduction of CA in Swaziland was a planned process and based on the implementation of activities in the FAO's awareness creation of conservation agriculture project in 2000. The activities were aimed at encouraging the adoption of CA among subsistence farmers in the country. Firstly, the project established four pilot areas in the four administrative regions of Swaziland complete with testing and validation units – TaVUs (for demonstrations) and relevant basic farming implements. The selected pilot areas include Shewula in Lubombo region; KaMbhoke in Shiselweni; Luve in Manzini and Motjane in Hhohho. To date three and five TaVUs exist at KaMbhoke and Shewula respectively while none at Luve and Motjane (Mlipha, 2010). The selection of the pilot areas appeared to have not considered the topographic and climatic conditions where the areas are located. For instance, while Luve and KaMbhoke are located in different administrative regions, they are apparently located within the same physiographic region which is the Middleveld.

Secondly, there was identification and selection of farmers and agricultural extension officers in the pilot areas to be trained in CA techniques according to the training-of-trainers mode. The selection criteria used were never explained in the literature which made it difficult to understand how the farmers were selected for the initial training. Thirdly, the project undertook a training programme involving seminars, workshops and excursions to demonstration sites of CA and its produce both within Swaziland and outside. Trainers were derived from regions with long experience of CA such as Latin America. While the manner in which the trainers were selected is logical however, inclusion of trainers from African countries would have added significant value to the training activities. Twenty six farmers and four extension officers acquired training in CA through the project's training programme undertaken from 2000 to 2005 (Mlipha 2010). The major thrust of the FAO project was to promote zero tillage and cultivation of indigenous crops with an intention to increase food production to combat current food insecurity and mitigate impacts of HIV/AIDS in rural areas. Other obvious basic tenets of CA were not emphasized in the initial training. These include crop rotation and weed management to name but a few. The assumption could be that these would be introduced to the farmers once they are acquainted with the basic principles of zero tillage and cultivation of indigenous crops. The few early adopting farmers were provided with farming implements, fencing materials as well as constant visitation and guidance by officers from FAO and Co-operation for the Development of Emerging Countries (COSPE), an Italian NGO. While this support is important to facilitate adoption of the system by the local subsistence farmers, there was a potential danger that the farmers may either develop a dependency syndrome or abandon practicing once the system once the support is discontinued.

2.4 PROSPECTS OF ADOPTION OF CONSERVATION AGRICULTURE IN SWAZILAND

Low level of adoption of CA has been noted in Swaziland and in the pilot areas but developments in the implementation of the FAO project activities point towards a brighter prospect of adoption of CA (Mlipha, 2004 & 2010; SADC ICART, 2009). The awareness raising coupled with provision of information inherent in the FAO project brightens the prospects of adoption of CA in Swaziland. Moreover, the training workshops yielded the critical activities such as the farmer-to-farmer campaigns currently taking place as well as the on-going training sessions on conservation agriculture in schools at Shewula and KaMbhoke targeting the youth (Mlipha, 2010). Community workshops, demonstrations and farmer-to-farmer campaigns contributed to the success of adoption of CA in Latin America (Derpsch, 2005b; Dumanski *et. al.,* 2006). The mentioned activities also have a potential to change the mindset of subsistence farmers and extension officers thus increase the prospects of adoption of CA in the country. The mindset, rooted in CF techniques, continues to be the biggest challenge to the acceptance and adoption of conservation agriculture by farmers, researchers and extension officers in Swaziland (FAO, undated).

The prospects of adoption of CA are further enhanced by the prevalence of basic farming practices relevant to conservation agriculture among traditional farmers (Sorenson, 1998). These techniques include intercropping, cultivation of indigenous crops and others. Subsistence farmers in Swaziland practice intercropping and cultivate ingenuous crops which are cornerstones of the introduction of CA in the country alongside zero tillage (Lado, *et. al.,* 2005; Chapter 3 below).

The benefits of CA, on their own, are adequate to increase the prospects of adoption of conservation agriculture among farmers (FAO, 2004). This is despite the absence of empirical data from the subsistence farmers pertaining to the benefits of the system. However, it is probable that the farmers would be attracted to benefits of CA which include relatively higher crop yields compared to conventional farming, low labour and inputs costs as well as a number of environmental benefits. While it has been proven that yields are relatively higher under CA however this is not true in the first few years of adoption yet farmers tend to be attracted by short-term benefits (FAO, 2005a). Higher crop yields accrue after a long period; say 20 years, of practicing CA (Derpsch, 2005a; Hobbs & Gupta, 2004). Farmers may also be enticed by reduction in labour requirements (numerically and in intensity) though the reduction also occurs after a long period of practicing CA (FAO, 2005a). The reduction in labour requirements could be of relief to subsistence farming in Swaziland where labour, particularly male labour, is depleted by impacts of HIV/AIDS and migration to areas with wage employment opportunities (VAC, 2003; World Vision Swaziland, 2010). It has been observed that in other countries zero tillage reduced labour inputs by up to 65% making CA attractive to HIV/AIDS affected areas (FAO, 2005a; Dumanski *et. al.,* 2006). Additional empirical data on the benefits of CA are presented in chapters 5 and 6 and deal with the improvement of soil nutrient content and water retention capacity among others.

Locally, the lower farming costs observed under CA enhances the prospects of adoption of the system by subsistence farmers (Dlamini & Masuku, 2011). The continued accumulation of organic matter in soils under CA improves soil fertility and moisture retention (Govaerts *et. al.,* 2006). In the long-term, 10-15% fertilizer efficiency is realized especially in grain cultivation (Kemper & Derpsch, 1981; Nielson *et. al.,* 2005; Dumanski, *et. al.,* 2006). Direct planting inherent in CA prevents loss of seed during planting and leads to reduced demand for seed. Moreover, few operations under CA demand heavy machinery especially since there is no tillage. Tractor hours are therefore reduced significantly while simple and less costly equipment is used (Dumanski, *et. al.,* 2006). Availability of local data especially on analysis of key soil parameters including water content and infiltration rates, organic matter content and ph. would have strengthened the discussion on prospects of adoption of CA.

The environmental benefits of CA may be less compelling to local farmers beyond basic benefits such as amelioration of soil fertility loss and soil erosion. In other contexts the prospects of adoption of conservation agriculture are enhanced by the potential soil carbon sequestration anticipated to off-set about 40% of estimated annual increase of carbon dioxide (CO_2) emissions (FAO, 2005a). Moreover, farmers stand to benefit financially from the carbon credit payments (Robbins, 2004). The benefits of trading carbon credits are currently being explored in South Africa and are encouraged by Nick Opperman, leader of farmers in South African (Business report, 2011). Overall, the benefits of CA to small scale farmers are substantial enough to encourage them to adopt the system (Sorenson, *et. al*., 1997; Sorenson, *et. al.,* 1998). Hence, CA is regarded as the most effective and beneficial farming system ever practiced by man-kind with financial benefits to farmers and ability to ameliorate soil erosion, conserve biodiversity and improves yields (Barker, *et. al.,* 1996; Sorenson, *et. al*., 1997; Sorenson, *et. al.,* 1998).

2.5 CHALLENGES TO THE ADOPTION OF CONSERVATION AGRICULTURE

It is now more than a decade since the introduction of CA in Swaziland. As noted above, the adoption rate is quite low as estimates from the Shewula pilot area indicate that about 5% of all the farmers practice CA at varying scales (Chapter 4 below). The adoption level is suspected to be even lower in other rural settlements outside the pilot areas. In the 10 years of introduction of conservation agriculture several challenges emerged constraining the successful adoption and practice of the system among local farmers. The major challenge that emerged has to do with problems of management of crop residue and maintenance of soil surface cover. This challenge was also ranked higher by regional champions of CA in a workshop held in Swaziland in 2009 (SADC ICART, 2009). In Swaziland, farmers in the communal Swazi Nation Land (SNL) practice a combination of crops and livestock farming. Culturally, it is the norm and also expected that livestock graze on crop residue especially in the winter season (Mlipha, 2010). The loss of crop residue curtails the accumulation of biomass and/or organic matter to improve soil fertility and protect it against soil erosion. This is a parallel to the American scenario where such a situation does not exist. To a large extent, CA is practiced by large-scale farmers with an intention to reduce production costs and increase farming profits (Derpsch, 2005a). In Swaziland, CA agriculture is targeted at the small scale subsistence farmers (FAO, 2000). The benefits accruing from the practice of CA including reduction of farming costs, conservation of soil moisture and fertility are more relevant to the resource poor farmers who are also subjected to the adverse impacts of climate change.

However, livestock farming can be integrated into CA in a number of ways (Business Report, 2011). Firstly, is through exploitation of the cycle of nutrients wherein livestock graze on crop residue and the kraal manure derived is used in farming as a way of returning organic matter to the soil. This may not be a panacea because it does not compensate for the loss of soil cover provided by crop residue. Secondly, it is recommended that forage crops be introduced in the rotation of crops for purposes of providing soil cover and fodder (Business Report, 2011). When doing that an immediate conflict ensues on which would be the paramount use of organic matter between soil cover and livestock feed. Moreover, subsistence farmers may not afford to grow fodder due to lack of adequate land and finance. Local subsistence farmers are currently struggling to meet their own basic food supply; and growing of livestock feed is therefore out of question (Mlipha, 2010). Thirdly, farmers are encouraged to control winter grazing by erecting fences around land under CA. Prohibition of winter grazing on cultivated land in SNL areas is not only a violation of the cultural norm of allowing livestock to roam uncontrolled during winter, but also a costly expenditure to the poor farmers. The challenges experienced in the management of crop residue on land under conservation agriculture has resulted in the suggestions for flexibility on the soil cover requirement in CA and intensification of water harvesting techniques in dry lands (RELMA, 2007).

The adoption of CA is at its infancy in the country. Adopting farmers experience challenges associated with initial land preparations including land leveling, clearance and others. These activities have high labour requirements and costs yet there is shortage of farm labour in the subsistence farming sector caused by various factors mentioned in 2.4 above (VAC, 2003; Swaziland World Vision, 2010).

Lack of farm equipment relevant for CA is among the major challenges experienced by farmers practicing the system in Swaziland and many parts of the world. It was only in the 1970s that the first CA tools were produced and intensification of production of such tools in Latin America facilitated a rapid adoption of CA (Derpsch, 2005a). Subsistence farmers on SNL areas currently own equipment exclusively suitable for CF and totally not suitable for the necessary operations associated with CA including land preparation, planting and weeding. One would project a general reluctance among farmers to discard their priced farming assets in view of the expenditure of their meagre finances to acquire CA equipment. The Project introducing CA in Swaziland has provided equipment relevant for the system in the pilot areas to facilitate its adoption. However, the equipment would soon be inadequate in the event more farmers adopt CA. It would be necessary for the country to consider establishing ways of producing or accessing such equipment by farmers. This may enhance the prospects of adoption of CA in Swaziland.

Lack of animal traction aggravates the lack of equipment situation. Many areas in southern Africa lost their livestock due to persistent drought which reduced livestock herds especially cattle resulting in lack of draught animals. Moreover, cattle rustling especially in areas neighbouring Mozambique has rendered many Swazi communities weak agriculturally due to lack of oxen that are the main targets of cattle rustlers. Compounding the situation is the lack of tractors in rural communities, resulting in farmers being delayed in commencing farming at an appropriate time. Any form of traction is essential in the initial preparation of the CA plots as well as in pulling some of the CA implements which may be heavy for human strength.

Another important challenge emerging from the introduction of CA in Swaziland is the need to change the farmers' mind-set that is currently focused on the practice of conventional farming techniques.. Local subsistence farmers find it difficult to relate to the zero tillage principle of CA. Local institutions of learning and agricultural extension officers still encourage the use of plough and harrow to prepare a seed bed for planting seed alongside attempts to encourage zero tillage. The practice of CF is still prevalent in the country despite it being viewed as costly and wasteful resulting in loss of organic matter and increase of surface run-off. Locally, and in some other countries, very few farmers adopted CA due to change in mind set especially that of adopting a farming system to ameliorate challenges posed by climate change, soil degradation, destruction of biodiversity and declining land quality particularly in the communal areas (Nyanga, *et. al.,* 2011). It is becoming apparent, therefore, that the adoption of CA by many farmers is in response to government policy and initiatives of collaborating. Adoption of CA in Zambia benefited from a clear and robust national policy while in Zimbabwe 5 to 10 % of commercial farmers adopted CA merely as a response to market forces (especially the rising costs of fuel) and not due to ecological or sustainability considerations (RELMA, 2007; Elwell, 1994). The fact that CA is so different from CF suddenly puts everything upside down and requires interested farmers to first forget everything about CF and be prepared to learn the new aspects of CA. Derpsch (2005a:4) observes that "as long as the head stays conventional it will be difficult to implement successful no-tillage in practice". Therefore, a radical change in the mind set of people involved in CA be they farmers, extension officers and scientists, is paramount otherwise this farming technique will not be brought to adequate adoption and application.

A further significant challenge and contradiction that emerged in the introduction of CA in Swaziland is the use of pesticides and herbicides. The expenses of herbicide are often built into an efficient CA once adopted successfully. The control of pests and weeds is done through burning of crop remains under CF which is of no cost to the farmers. However, the retention of residue of previous crops associated with CA creates a haven for pests while the no-tillage practice allows weed residue to germinate and compete with the new crop (Fowler, 1999). Modern farm chemicals have proved effective in controlling weeds and pests, however, the associated expenses eliminate all the gains achieved through no-tillage. It is important to guard against a situation where the costs saved from no-tillage are easily defrayed by increased chemical expenditures. Moreover, increased agrochemical usage results in environmental problems mainly water and air pollution. In that case, the use pesticides and herbicides fly in the face of the fundamental CA feature of being environmentally sound.

The poor quality of soils in the pilot areas is another limiting factor to the adoption of CA in the country. The soils at Shewula and KaMbhoke are poor sandy loams with high water infiltration and prone to loss of soil nutrients through leaching. Introduction of CA in Swaziland targeted mainly areas with low soil quality and prone to drought. Locally poor sandy loams are normally treated with addition of organic matter (manure) and lime. However, soils with high infiltration rates are prone to rapid loss of soil nutrients particularly through leaching during periods of heavy rainfall. There is also the problem of crusting which has been found not to be much a problem under CA because of the presence of soil cover. In Latin Americas CA is practiced on highly productive soils while in Swaziland the focus is on marginal soils with high risk of degradation (Derpsch, 2005b). This may have a negative impact on the farmers should the yields fail to show any significant improvements from those realised under CF on similar soils.

2.6 CONCLUSION

In Swaziland, the introduction of CA was intended to respond to the problems of food shortage (food insecurity) among subsistence farmers as well as impacts of persistent drought and soil infertility. Moreover, the adoption of CA was viewed as crucial for subsistence farmers owing to its potential to reduce farming costs and improve crop yields. In Swaziland CA entails practice of a bundle of farming principles centred on zero tillage and involves cultivation of indigenous crops through intercropping while maintaining a permanent soil cover. While the study succeeded to identify factors that enhance the prospects of adoption of CA by subsistence farmers in Swaziland, it lacked empirical data in support of some factors identified as being crucial to motivate the farmers to adopt the system. As a literature survey-based study it was difficult to access reports containing data on the benefits of CA for local farmers, especially data on yields and labour and financial inputs. Therefore, the prospects which were highlighted in the study were projected to be brighter were based mainly on the manner which CA was introduced into the country and that its introduction was a deliberate government effort to improve agriculture in the country.

The study highlighted that the process of introduction of CA in Swaziland experienced a number of challenges. Despite the lack of empirical data the literature revealed that the challenges include problems of management of crop residue and maintenance of soil cover. This is due to traditional practices of feeding crop residue to livestock especially during the culturally sanctioned winter grazing. Other challenges include lack of appropriate CA equipment, shortage of labour and traction power as well as the prevailing mind set among farmers and agriculture extension officers that remain rooted in CF techniques.

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CHAPTER 3

THE STATUS OF CROP CULTIVATION, CROPPING PATTERNS AND FACTORS GUIDING THE SELECTION OF CROPS BY SUBSISTENCE FARMERS AT SHEWULA, SWAZILAND

3.1 INTRODUCTION

3.1.1 Background

Swaziland's agricultural policy revolve around the achievement of basic household food security, improvement of national nutritional levels, rural incomes and the sustainable use of natural resources at national level (Government of Swaziland, 1997). Despite massive financial infusion into the programmes aimed at the achievement of the national agricultural objectives, particularly the Rural Development Areas Programme (RDAP), food security has remained an elusive objective to date (Swaziland Vulnerability Assessment Committee, 2010; IRIN, 2012: WFP, 2013). About 10% of the population experienced food shortage in 2012 (WFP, 2013). The lack of achievement of improved agricultural production (especially maize) and food security is mainly attributed to erratic rainfall with persistent droughts, reliance on archaic agricultural practices, impacts of HIV/AIDS and escalation in poverty levels (FAO, (2008); IRIN, 2012). Changes in the approaches to bolster agricultural production and achieve food security amid the constraints noted above were inevitable. One of the approaches was the introduction of conservation agriculture (CA) into Swaziland in 2000, owing to its success in improving agricultural production in other semi-arid parts of the world (Nielsen, *et. al.,* 2005; FAO, 2000). Conservation agriculture is viewed as a mix of farming techniques essential for soil and water conservation while building a stable structure for sustainable crop production and diversity (FAO, 2008). Paramount to CA is the practice of minimum or zero tillage alongside maintenance of soil cover from stubble of previous crop and cultivation of variety of traditional crops (Dumanski *et. al.* 2006; FAO, undated).

The introduction of CA was a deliberate effort by the government of Swaziland, in collaboration with the FAO and COSPE (Cooperation for the Development of Emerging Countries), through a project titled *"Awareness Creation of Conservation Agriculture" – TCP/SWA/2909 (T)*. The project was built around the notion of careful selection of crops that are drought tolerant and of high nutritional value coupled with soil and water conservation principles (Mlipha, 2004). Hence the first workshop on CA held at Shewula in February 2002 centred on the theme *"Use of Indigenous Species for Sustainable Development towards Food Security"*. The promotion of cultivation of indigenous crops was used by the FAO project as a medium for facilitating the adoption of CA in the country. Therefore, the cultivation of traditional crops does not equate to adoption of CA but as litmus for testing the likelihood for adoption of the system.

The zero tillage associated with CA reduces soil erosion, while the cultivation of indigenous or traditional crops ensures improvement of crop production as they are deemed to be drought and pest resistant (Russell, 1996; Nielsen, *et. al.,* 2005). The intercropping and crop rotation aspects, inherent in CA, also sustain crop production in adverse climatic and soil conditions (Rouanet, 1984). There is, therefore, a need to ascertain the crop cultivation status as well as study the cropping pattern and factors farmers consider when selecting crops to cultivate to establish the status under which CA is introduced at Shewula. This information would provide an indication of the likelihood for the farmers to adopt and practice CA in the area.

In a technologically driven commercial agricultural system the prevailing parameters such as soil characteristics and fertility, climate, water availability as well as mathematical models drive the process of crop selection (Nielsen *et.al.* 2005; Ingels, 1994). Are these approaches significant or relevant to the subsistence farmers at Shewula? It could be assumed that such approaches may not be applicable in the traditional setting such as Shewula where scientific expertise is lacking. A question arises as to what informs the subsistence farmers in selecting which crops to cultivate and from what selection options available to them. Further, once selected, how are the crops cultivated? It is, therefore, necessary to ascertain the factors farmers consider in the selection and cultivation of the crops within a traditional and technology deficient context.

3.1.2 Brief description of Shewula

Shewula is located in the northern-eastern part of Swaziland on the Lubombo plateau at about 500 metres above sea level. The area experiences relatively dry spells with a long term annual average rainfall of about 700mm, which it has failed to reach for past 10 years due to persistent drought gripping the country. Day time temperatures are generally warmer in summer averaging about 27°c and cool winter averaging about 10°c. Shewula is characterised by a rugged escarpment terrain and indigenous woodlands stretching along the Mbuluzi River. The rugged terrain confines cultivation of crops to the pockets of gentle sloping land along the narrow river valleys on the escarpment. The soils are predominantly *lithosols* dominated by shallow grey loam resting on hard rock and the young shallow brown-black loam to clay soils. Shewula experiences persistent drought spells which have significance effects on the production of food crops such as maize yet 80% of the approximately 10 000 people of Shewula area depend on rain fed subsistence farming for their livelihood. The remainder is engaged in wage based employment in the neighbouring commercial sugar-cane plantations and private farms. Maize, being a staple food, is grown on a wide scale at Shewula and the yields, reflect the national situation, are continuously declining due to the persistent drought, lack of tractors and animal traction, limited access to agricultural inputs and impacts of HIV/AIDS (Mlipha, 2005; Save the Children Fund, 2003; IRIN, 2012; WFP; 2013). There are a variety of other crops grown including traditional crops such as jugo beans, cassava, pearl millet to name a few, albeit on a small scale, which are yet to be documented. Moreover, Shewula is within the foot and mouth disease quarantine area which places constraints on selling of livestock in times of need. As a result the cattle herds are relatively small per homestead (Mlipha, 2004).

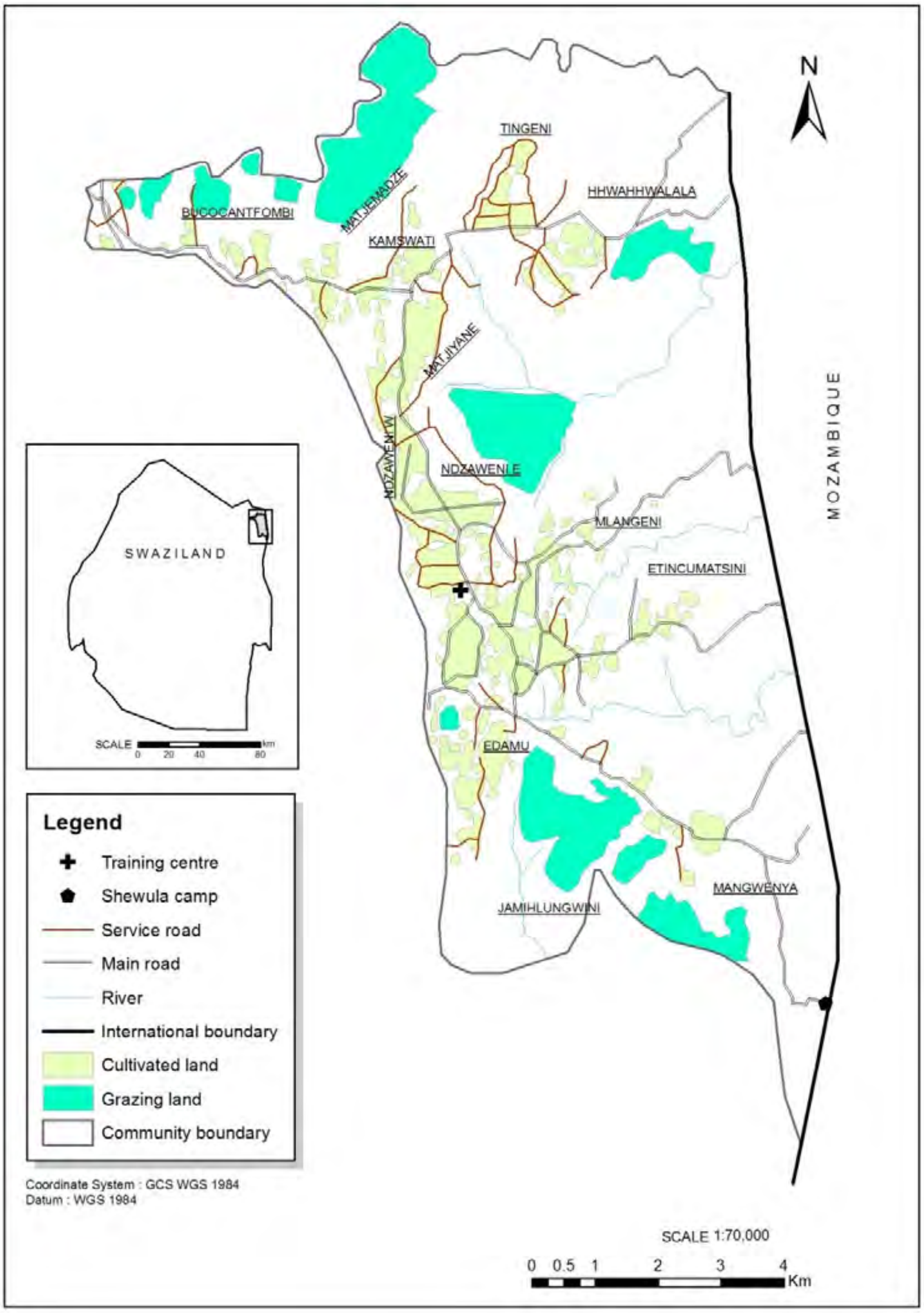

Figure 3.1 Map of Shewula showing the dominant agricultural land uses

3.2 METHODOLOGY

3.2.1 Data Collection Techniques

The study used the quantitative survey method and was complemented by key informant interviews. A questionnaire was used to collect the requisite data and was administered to respondents by trained research assistants through face-to-face interviews (Appendix A). During the survey only heads of households (irrespective of gender) who were involved in farming were interviewed. The questionnaire solicited data pertaining to basic demographic details of the farmers; types of crops cultivated; patterns of crop cultivation; reasons for cultivation of the crops and other general farming details. Key informant interviews were conducted involving the Agriculture extension officer based at Shewula and a well-known farmer by the name of *Mazoli* (*pseudo* name used for ethical reasons) who is famous for the re-introduction of the "indigenous" maize seed at Shewula. The seed has now assumed his name. Key informant interviews were open-ended and benefited from periodic prompts from the researcher. The analysis of data was mainly based on descriptive statistics to establish means, frequencies and proportions of data collected and responses from the responses.

3.2.2 Sample Size and Sampling Procedure

Sample homesteads were derived from approximately 900 owners in the 13 sub-areas of Shewula. Due to the large number of homesteads as well as time and financial constrains 93 homesteads (10%) were selected for the survey. Systematic random sampling procedure was used to select the sample homesteads based on the lists of names of homestead heads obtained from community sub-leaders (*Bosigodzi*). Systematic random sampling is an equal probability method where the population is arranged according to a list and every n^{th} element in the list is chosen for inclusion in the sample after the first element has been selected randomly (Castillo, 2009). In this study the first homestead was selected using enumerator values drawn from a table of random numbers and thereafter every 10^{th} homestead was selected for inclusion in the sample. The identities of the respondents and data acquired from them were obscured in accordance with requirements for ethical considerations in research.

3.3 RESULTS

The nature of data collected did not require any advanced statistical manipulations. Nevertheless, the use of SPSS (v. 20) allowed for the presentation of basic descriptive statistics such as averages and frequencies as well as generation of tables and graphs for data representation. Farmers' opinions were presented as statements and quotations.

3.3.1 Gender and age of farmers interviewed

Since all homesteads practice farming, all homestead owners are therefore referred to as farmers. Female farmers accounted for 85% while 15% were males. The skewedness of gender towards females may be due to a number of reasons. Though the reasons were never solicited during the survey but it is probable that some male heads of households were away in pursuit of wage employment outside of Shewula while some may have passed on. The majority (95 %) of the farmers were aged 30 years and above while very few farmers (4%) were below 30 years old. Only 5 farmers were above 70 years old. This is against the prevailing notion that child-headed households are prevalent as a result of increased adult mortality due HIV/AIDS related diseases. The HIV/AIDS infection rate is quite high in the country as it is currently estimated at about 25% of the adult population (Central Statistical Office (CSO) Swaziland & Macro International Inc., 2008).

3.3.2 Size of land cultivated per farmer

Most of the farmers cultivate small land holdings where 15% of the farmers cultivate less than a hectare of land while 71% cultivate less than 2 hectares of land (Figure 3.2). Only 4.3% of the farmers cultivate more than 3 hectare parcels of land.

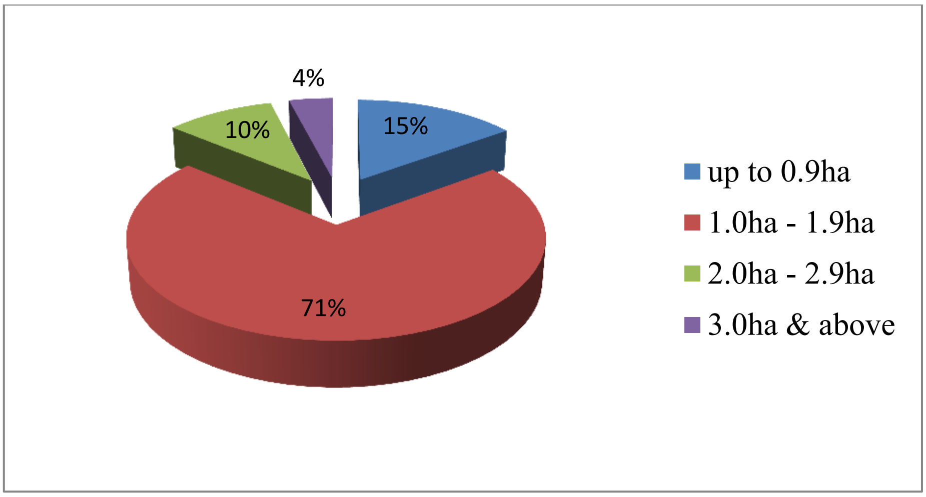

Figure 3.2 Sizes of land cultivated by farmers at Shewula area in hectares

There are no standards pertaining to size in the allocation of land to farmers under the Swazi Nation Land tenure system; hence the diversity in the sizes of land owned by the farmers. Absentee land lords are very rare in Swaziland and there is no landownership that is temporary. It has been noted that sizes of cultivation land available to farmers has an influence in the selection of crops for cultivation. For instance, farmers cultivating larger amounts of land tend to cultivate highly diverse crops varieties than farmers cultivating smaller land (Cromwell & van Oosternhout, 2000).

3.3.3 Types of crops cultivated

Farmers at Shewula cultivate a limited variety of crops as indicated in Table 1 below. The most popular crops are maize and pumpkins which are cultivated by all the farmers. A significant proportion (86%) of the farmers cultivates peanuts (*Arachis hypogea* L); 78.5% cultivate beans, 63.4% cultivate *jugo* beans (*Vigna Subterranea* L*)* and only 44.0% cultivate cowpeas (*Vigna unguiculata* L.). Cassava (*Manihot esculenta* L) and sorghum (*sorghum bicolour* E) are drought tolerant crops, yet only 36.6% and 11% of the farmers respectively cultivate these crops despite Shewula being situated in the drought prone physiographic region of Swaziland. Other crops cultivated by farmers at Shewula albeit on small scale are in Table 3.1 below. Key informants mentioned that a few farmers cultivate *mung* beans (*Vigna radiate* L.), a traditional drought resistant cereal whose roasted powder last a long time without getting spoiled. Hence in yesteryears it was used as provision for long distance travellers. Key informants also mentioned that all the crops mentioned above are regarded by local farmers as indigenous including maize. Biologically, maize is exotic in Swaziland but due to it being traditionally regarded as a staple food for the Swazi people it is now taken as an indigenous crop. Actually, only maize produced from hybrid is viewed as exotic.

Table 3.1 Types of crops cultivated by farmers and magnitude of their cultivation, 2008/9

Types of crops	Extent of cultivation	
	No. of farmers	% of farmers
Maize	93	100
Pumpkins	93	100
Peanuts	75	80.6
Beans	73	78.5
Jugo beans	59	63.4
Cowpeas	41	44.0
Cassava	34	36.6
Sugar beet	34	36.6
Sweet potatoes	20	21.5
Sorghum	11	11.8

The crop diversity is said to be limited in the sense that the source of starch in the diet at Shewula is only from maize as fewer farmers cultivate sorghum and cassava yet in other countries besides maize farmers grow yams, millet, various cultivars of potatoes and other sources of starch (Brush, 2000). The limited selection of crops at Shewula is caused by a number of factors to be discussed below however is highly probable that inadequate land for farming available to farmers could be one of the factors. Data on area of land under which the crops in Table 3.1 above are cultivated and yields realised from their cultivation the crops was not solicited. Subsistence farmers do not keep records of their yields and the amount of land dedicated to cultivation of a particular crop is not systematically planned.

3.3.4 Crops farmers wished to cultivate had conditions been ideal

This data was acquired to establish the nature and range of crops the farmers wished to cultivate had conditions been ideal. The nature and range of crops in the farmers' wish list as portrayed in Table 2 below do not differ much from the list of crops they are already cultivating (Table 3.2).

This indicates that farmers are more or less satisfied with their current choice of crops. Only three new crops were mentioned in the wish list and they include vegetables, sugar-cane and cotton. Besides cotton, vegetables and sugar-cane require large and reliable water supply for irrigation and Shewula lacks such in the absence of sizeable perennial streams on the Lubombo plateau. Sorghum remains an unpopular crop among the farmers despite it being drought resistant. This may be due to its unfamiliar colour and taste as a starch substitute for maize.

Table 3.2 Crops farmers wished to cultivate had conditions been ideal

Crops farmers wished to cultivate	No. of farmers	% of farmers
Cotton	5	5.4
Sugar-cane	1	1.1
Vegetables	4	4.3
Cassava	20	21.5
Sorghum	6	6.5
Beans	24	25.8
Sweet potatoes	10	10.8
Soya beans	13	14.0
Peanuts	10	14.8
Total	**93**	**100.0**

3.3.5 Sources of seeds for crops cultivated

The seeds for crops cultivated by subsistence farmers at Shewula are acquired locally; where 54% of the farmers acquire their seeds from the previous crop while 5% acquire seeds from other farmers in the area. However, about 32% of the farmers, which is a significant proportion, purchase their seeds from local shops (Figure 3.3). Key informants mentioned that farmers cultivate two types of maize seed: one perceived to be traditional is propagated by the farmers themselves and the other is derived from hybrid seed acquired from the shops. Moreover, local seed shops sell seeds for various traditional crops however such seed is not perceived as traditional by the local farmers. This has resulted in the promotion of seed multiplication and storage initiatives in the local communities. The intention of this initiative is to address the problem of access to traditional seeds by farmers as well as conserve the seeds for future use. Moreover, the initiative may also counter the ever increasing seed prices in retail shops.

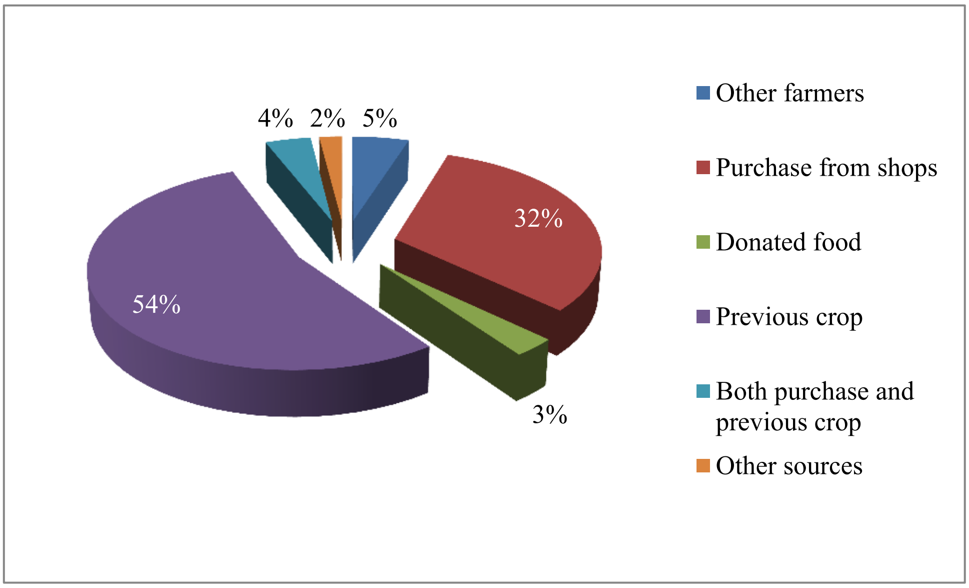

Figure 3.3 Sources of seeds for famers at Shewula

3.3.6 Cropping pattern

The results show that 74 (80%) of the farmers practice intercropping and 19 (20%) practice mono-cropping. Apparently, intercropping is a common practice among the farmers but mono-cropping practiced as it was a condition set by maize dealers (in their attempt to increase maize production) for farmers to access credit for farm inputs.

3.3.6.1 Intercropping

Three main intercropping combinations were identified and all combinations involve two crops with maize as a common and major crop in all combinations. Combinations involving more than two crops were not reported by the farmers and key informants mentioned that occurrence of such was rare at Shewula. Table 3.3 below shows that maize and pumpkins are the most dominant crop combination cultivated by about 81% of the intercropping farmers who dedicated their entire land to cultivation of the two crops simultaneously. The other combination of cow peas is cultivated about 12% of the farmers who dedicated portions of about 80% for cultivation of the two crops simultaneously. Maize and beans is the least cultivated combination and only 50% of farming land was dedicated to cultivation of this combination. Other combinations involving maize and crops such as sugar beet, calabash (*Langeria siceraria* L.) were noted but occurring at a very low scale. On the significance of intercropping, the key informants only mentioned that it is the traditional way of growing crops at Shewula that has been practiced since their living memory and has been passed from generation to another. All crops at Shewula are cultivated under rain fed conditions once in the summer of every year.

Table 3.3 Major crop combinations and estimated percentage of land coverage

Crop combinations	No. of farmers n=74	% of farmers	% of cultivated land
Maize and pumpkins	60	81.1	100
Maize and cowpeas	9	12.1	80
Maize and beans	5	6.8	50

3.3.6.2 Mono-cropping

Key informants mentioned that mono-cropping was common among maize farmers supported by external maize promotion agents who provide farmers with basic farm inputs such as hybrid seed, fertilizers, pesticides and herbicides and traction. This makes mono-cropping of maize more of a foreign-driven practice compared to other crops under monoculture. About 84% of the mono-cropping farmers cultivate maize in their entire farming land. Farmers practicing mono-cropping of other crops such as beans, *jugo* beans and sweet potatoes, are very few and also dedicated smaller portions of their land to cultivating such crops compared to maize mono-cropping (Table 3.4). Reasons for mono-cropping beans was that they are usually cultivated later than maize normally towards the end of January while sweet potatoes are perceived to perform poorly when cultivated simultaneously with other crops. *Jugo* beans, on their part, are always cultivated on virgin land or land that has been under a long period of fallow. Such land is not readily available to small scale subsistence farmers at Shewula hence the small proportion of land dedicated to cultivation of *jugo* beans.

Table 3.4 Crops commonly cultivated individually and estimated percentage of cultivated land they cover

Crop	Number of farmers n=19	% of farmers	% of cultivated land
Maize	16	84.20	100
Beans	1	5.26	40
Jugo beans	1	5.26	20
Sweet potatoes	1	5.26	20

3.3.7 Responsibility for crop selection

To a large extent the selection of crops for cultivation appears to be a prerogative of members of the homestead commanding authority through ownership of household resources such as land, finances, equipment to name a few, which are crucial for farming. Table 3.5 below indicates that about 65% of the farmers believe that mothers have the responsibility to select crops for cultivation while 28% believed that the responsibility was for fathers. Only on rare occasions where grandparents and eldest sons assume the responsibility to select crops for cultivation. It can be assumed that this occurs where the parents are no longer living or the eldest sons provide the finance for payment of farm inputs and mechanical traction.

Table 3.5 Responsibility to select crops for cultivation in a homestead at Shewula

Responsibility to select crops	No of farmers	% of farmers
Father	26	28.0
Mother	61	65.6
Grandparents	4	4.3
Eldest son	2	2.2
Total	**93**	**100.0**

The findings reveal a very subtle gender perspective on selection of crops especially the fact that mothers and/or eldest sons select crops deliberately ignoring the eldest daughters. Women appear to hold the responsibility to select crops to be cultivated because they constituted a majority of the respondents as males were mostly away from home during the survey. The key informants mentioned that despite women being in position to select crops for cultivation they were culturally not at liberty to cultivate any crop. About 63% of the farmers mentioned that male heads of homesteads normally assume the responsibility to cultivate crops of critical household value in terms of consumption and income generation such as maize. However, this situation does not apply in about 37% of the farmers. Moreover, more than 90% of the farmers mentioned that cultivation of pumpkins and leguminous crops is exclusively for female members of the homesteads.

3.3.8 Factors considered by farmers in the selection of crops for cultivation

The farmers were requested to state factors they consider in the selection of the crops they are cultivating as reflected in Table 3.1 above. To further tease out more factors guiding the selection of crops to be cultivated the farmers were also requested to state the major factors constraining them from cultivating the crops included in their wish list in Table 3.2 above.

3.3.8.1 Factors considered by farmers in the selection of crops they are cultivating

The farmers raised five factors they considered in the selection of crops they are currently cultivating and they include; selection of crops for being drought tolerant, resistant to pests, early maturity, higher yields and medicinal properties (Figure 3.4).

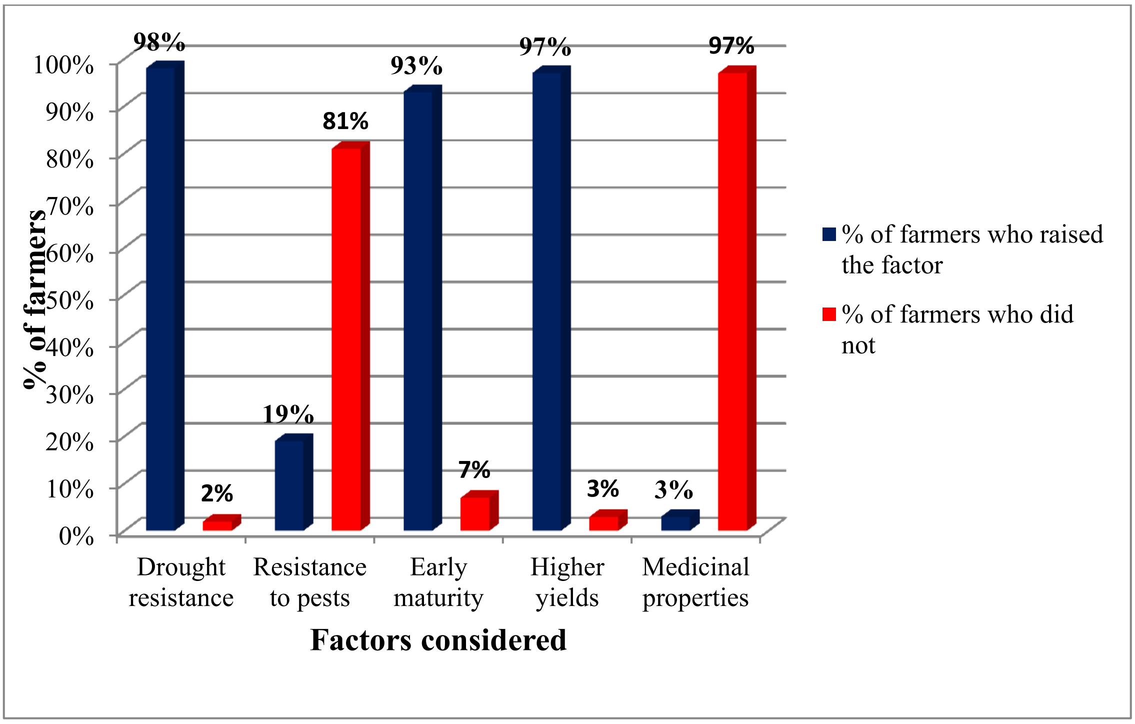

Figure 3.4 Factors considered by farmers in the selection of crops they are cultivating

It appears that over 90% of the farmers are inclined towards selection of crops which have the ability to withstand drought, mature early and produce high yields. Only about 19% and 3% respectively of the farmers selected crops having considered their resistance to pest and medicinal properties. Consideration of drought resistance and early maturing characteristics of crops reflects the prevailing drought context under which cultivation of crops is undertaken at Shewula. Drought resistant and early maturing crops are perceived to thrive better under the prevailing conditions of short spells of rainfall characteristic of the current erratic pattern of rainfall during the cultivation season.

3.3.8.2 Factors constraining selection of crops for cultivation

A significant proportion of the farmers (47%) identified lack of finance as a major constraining factor to selection of crops to cultivate while about 26% and 24% are constrained by lack adequate farming land and drought respectively (Figure 3.5). Only a very small proportion (3%) of the farmers perceived health problems as a constraining factor in the selection of crops to cultivate. It is of interest to note that all the 93 farmers surveyed raised only four constraining factors, yet more constraints are assumed to exist including poor soil quality, poor terrain, lack of government support as well as those related to lack training and capacity building programmes. Moreover, drought was perceived as a lesser constraint compared to lack of finance and inadequate land despite the frequent dry spells persistently gripping Shewula during the farming seasons.

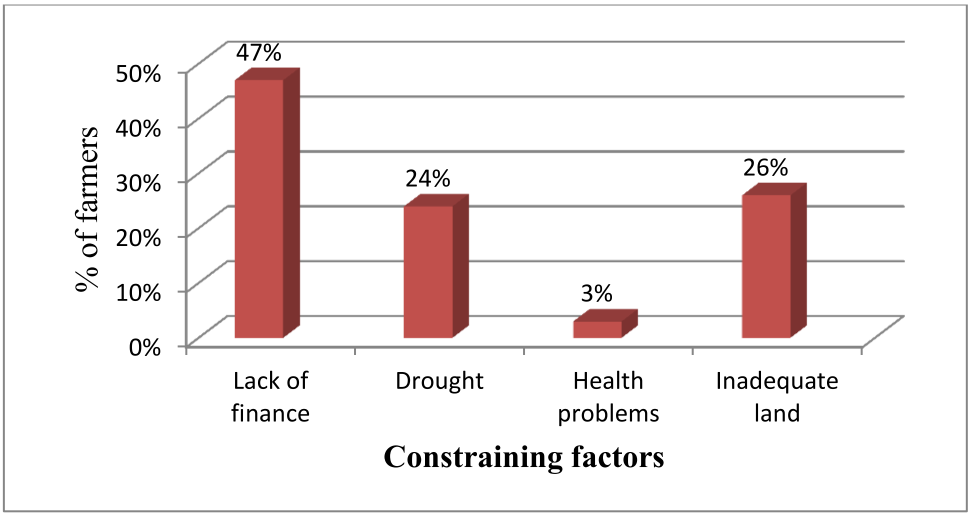

Figure 3.5 Factors constraining farmers from growing crops at Shewula

The factors presented in Figures 3.4 and 3.5 above give different but converging factors which were raised based on both reality (Figure 3.4) and imaginary wishful circumstances (Figure 3.5). What emerges is a list of factors that is reflective of prevailing circumstances which influence decisions on types of crops to be cultivated. From the data the farmers are clearly preoccupied with the prevailing drought and availability of resources to mitigate its impacts on farming. Hence drought, lack of financial resources and associated factors are deemed significant in influencing decision made on crops to be cultivated. For instance, over 95% of the farmers selected indigenous maize and legumes for their ability to withstand drought and produce higher yields compared to other crops. About 50% of the farmers indicated that the cultivation of hybrid maize is mainly for its early maturity advantage. Very few (19%) farmers selected to cultivate legumes based only on their ability to withstand pests. There are also 3% of the farmers who recognized balsam pear (*inkakha)* as possessing some medicinal properties though it is a wild plant that tends to grow close or within human settlements.

3.4 DISCUSSION

Understanding the basic attributes of the farmers at Shewula is critical to appreciate the types of crops they grow and the factors they consider in their selection. The farmers were found to be predominantly women aged 20 years and above with a majority within 41 – 50 years cohort. This dispels the popular assumption that most homesteads are female headed and existence of many child-headed homesteads in rural areas as a result of HIV/AIDS related deaths. Only two homesteads were headed by people below 20 years old at Shewula. The prevalence of female farmers did not imply prevalence of female headed households as 65% of homesteads are headed by males in the Lubombo region (VAC, 2014). The prevalence of more female farmers is attributed, in part to the absence of males engaged in salaried employment outside Shewula. In that case the males were found to be merely absentee farmers who delegate the farming responsibilities to their female spouses for the duration of their absence. This is so because some of the males return to their homesteads during farming seasons to assume their farming responsibilities especially the selection of crops for cultivation; hence the increase of the proportion of males responsible for selection of crops for cultivation from 15% in the sample to 26% (Table 3.2). In case of the demise of the male homestead heads women assume full farming responsibilities.

Farmers at Shewula cultivate limited types of crops on a recognisable scale as indicated in Table 3.1 above. They appear to focus on the cultivation of traditional food crops, especially maize, where the seeds are mainly acquired locally. Lado *et. al*. (2005) established a similar situation at Zombodze South (complete name of the area since there are two areas called Zombodze) south-eastern Swaziland, where most farmers cultivate mainly two crops; maize and beans for subsistence purposes. In Zimbabwe poor farmers dedicate greater portions of their land to cultivation of the main grain which is maize and few other crops (Cromwell & van Oosternhout, 2000). The findings reflect the general preference for maize, the national staple food which accounts for between 70% and 85% of the total cereal consumption while the maize crop covers about 80% of the total cropland area on Swazi Nation Land (SNL) tenure system (Economic Planning Office, 2004, Mamba, 2003; AECOM International Development, 2012). The SNL is communal land administered by traditional authorities (chiefs) on behalf of the monarch and people enjoy user rights without legal title to land. The use of locally available seed is also common nationally though cases of use of purchased seed exist but of serious concern at Shewula is the use of donated grain from relief agencies as seed. This raises serious environmental concerns considering the prevalence of alien and invasive plants in the area that may be attributed to this indiscretion among the local people. Moreover, dangers associated with the cultivation of genetically modified organisms (GMOs) coming with relief food donations and purchased seeds may not be ruled out.

The fact that farmers cultivate traditional crops bodes well with the prospects of success of adoption of CA in the area and nationally. It has been observed that traditional crops are cultivated mainly for their vigour, drought and disease resistance, low demand for rainfall, fertilizers, pesticides as well as protection of soil against degradation (Gerik, 2000; Poiret, 1995). At Shewula traditional crops are cultivated mainly for their perceived ability to withstand drought, yield higher and resistance to pests (Figure 3.4). However, hybrid maize is cultivated for is ability to escape the dry periods during short spells of rainfall during the summer season as it takes a shorter time to mature compared to traditional maize. Cognisant of the various advantages and abilities of traditional crops, promotion of their cultivation by subsistence farmers is the central thrust of the project introducing CA in the country (FAO, 2000). The cultivation of traditional crops does not in any way implies adoption of CA however traditional crops were used by the project introducing CA as a vehicle to facilitate its adoption by the local farmers. The limited number of crops the farmers wished to cultivate had conditions been ideal was not anticipated since wish lists by their nature tend to be long. It transpired that the farmers are conscious of their limited resources and the drought to get carried away by imaginary scenarios.

Traditionally, African farmers select and cultivate crops in combinations and that is intercropping (Rosenzweig and Parry*,* 1994). This view is held while cognisant of the fact that crop cultivation systems underwent major changes between 1975 and 1990, which impacted on the current pattern of crop cultivation which now shows some traces of monoculture (Ingels, 1994). Pressures to increase crop production especially cereals precipitated the change in the patterns of crop cultivation particularly with the influence of increased prices attached to cereals. Consequently, specialized farming, with monoculture tendencies, emerged even among small scale traditional farmers (Poiret, 1995). The changes also had considerable influences on the manner subsistence farmers selected crops for cultivation. At Shewula mono-cropping tendencies exist but they are confined to 20% of the farmers. These farmers are mainly successful maize growers who are mostly members of an agricultural inputs credit scheme aimed at increasing maize production run by the local Chinese Agricultural Mission. Monoculture is prevalent at Zombodze south where 80% of the farmers grow maize under monoculture and the farmers appear to attach low priority to intercropping (Lado *et.al.* 2005). Maize agents and general dictates of increasing crop yields discourage intercropping on assumption that other crops compete with maize for water, nutrients and sunshine resulting in decline of yield. However, intercropping at Shewula is prevalent, being practiced by close to 80% of the farmers. Unlike Zombodze south, Shewula is not a major maize producing area as it lies on the Lubombo plateau that is one of the drought prone regions in Swaziland alongside the Lowveld. Thus it is not a hive of maize dealers and agents seeking to increase maize production.

Nevertheless, the tendencies among subsistence farmers in Swaziland towards monoculture seem to be inevitable under the circumstances noted above but intriguing at the same time considering the massive benefits associated with intercropping. Lado *et. al.* (2005) observed that mostly female farmers practice intercropping nationally and this seems to hold sway considering that 85% of the farmers at Shewula are females and intercropping is prevalent. Contrary to claims that most farmers in Africa 'intercrop anything with everything' (Mohammed-Saleem, 1999), this is not the case at Shewula where intercropping is not a mere random mixture of crops but a careful crop selection process aimed at always including maize, the national staple crop, in all the intercropping combinations. Similar situations were also noted in other parts of Swaziland and sub-Saharan Africa where all crop combinations cultivated by intercropping farmers involved maize (Rouanet, 1984; Lado *et.al*., 2005).

The intercropping farmers at Shewula gave very few and simplistic reasons why they practice intercropping. Their common perspective for intercropping is that it was a traditional or cultural way of growing crops. Understandably, traditional farmers at times grow crops for their social value rather than economic or environmental (Benin, *et.al.* 2004). However, the small size of land cultivated by the farmers, as noted in Figure 3.2 above, compels them to intercrop thus to maximise land utilization and increase crop yields. The situation obtaining at Shewula is common in sub-Saharan Africa where intercropping is crucial for crop cultivation where land holdings are small (Mohammed-Saleem, 1999). However, some farmers mentioned that intercropping provides some guarantee of yield from other crops despite the failure of the main crop (maize) due primarily to drought or other factors. Proponents of intercropping highlight its climatic significance as it provides farmers with flexibility for crop selection and cultivation across variable climatic conditions (Rosenzweig and Parry, 1994). Moreover, other purposes of intercropping include provision of soil cover to lower soil temperatures, increase water infiltration, prevent soil erosion, lower incidence of plant pests and diseases as well as reduce labour needed for weeding (Jose, 2003, Mohammed-Saleem, 1999; Gbetibou and Hassan, 2005; Kurukulasuriya and Mendelson, 2006). By combining different plant properties such as height, root depth, and maturity period, intercropped plants complement each other in the use of light, water, and nutrients. Hence, output in intercropped land is said to be higher than in mono-cropped yields (FAO, 1990). There are other benefits that accrue from the practice of intercropping including optimized output over a long period of time (sustainable production), maintenance of agro-ecosystem diversity; build-up of soil fertility, prevention of nutrient loss, and provision of continuous soil cover. Intercropping is one of the basic techniques of CA and its widespread practice at Shewula is crucial in the acceptance and adoption of CA. After all, intercropping would portray CA not as a completely new and foreign concept as it would be the case where mono cropping is prevalent.

Proper selection of crops for cultivation is important and so far it has been indicated that it is not a random process that can be performed by anybody but specific individuals in the homestead and is guided by socio-economic and biophysical factors. The study reveals that crop selection is predominantly done by elders or any persons of significance who control household resources such as land and finance and have farming experience. The respondents also recognised that traditionally crop selection is a prerogative of male heads of homesteads but due to circumstances noted above females are increasingly assuming that responsibility. Venkatesan and Kampen, (1998), after working on crop selection with several rural communities in sub-Saharan Africa, also concluded that crop selection is a prerogative of elderly males within traditional homesteads. However, in practice this state of affairs does not obtain entirely at Shewula. The gender composition of the farmers showed dominance of female which implies that the process of crop selection and cultivation is literally and practically the prerogative of women. But it was noted above that some male heads of homestead, especially those in wage employment sometimes return to their homesteads during the farming season to assume their role of selection of crops for cultivation. Moreover, a link between gender and cultivation of certain crops was established and found to be consistent with the local prevailing traditional set-up where male heads focussed on maize cultivation while females were responsible for cultivation of pumpkins, legumes and tubers (Lado *et.al*., 2005).

With regard to factors guiding the selection of crops for cultivation, absolute marketing motives as influence to the selection of crops for cultivation were never established at Shewula. But there are very few successful farmers who are able to sell surplus maize in times of good harvest. However, it is undisputed that financial considerations do influence the crop selecting process coupled with other factors such as prevailing climatic conditions (drought), limited access to land, the productivity attributes, and the state of health of the farmers. Most of the farmers are not in gainful employment and have limited financial resources yet costs for farm inputs and traction are not only high but increase annually. Nationally, 70% of the people living below the UN designated poverty line of one US Dollar per day and have uncertain incomes are found in rural areas like Shewula (Ministry of Economic Planning, 2007; UNDP, 2011; FinScope, 2011).

The farmers also considered the small land they cultivate when selecting crops to cultivate. Figure 3.2 above shows almost 85% of the farmers cultivated less than 2 hectares of farmland. Small sizes of land limit farmers' flexibility to select a wide range of crops and they end up being confined to a few crops especially those crucial for household consumption (Helfand and Levine, 2004). This is the obtaining situation at Shewula where farmers regarded access to inadequate land for cultivation as one of the major constraints to selection of crops for cultivation. Consolidation of land into large parcels land for farming purposes either through formation of farming cooperatives or other means has a potential to address the land question. However, such land arrangements are unfamiliar to subsistence farmers on SNL. Cooperatives, in particular, are formed by local farmers mainly for bulk acquisition of farm inputs where they benefit from economies of scale. Therefore, it could be argued that advancements in farming technology are necessary to improve agricultural productivity and allow farmers the possibility to diversify their crops to realise higher yields even in the prevailing poor access to land.

Some farmers with access to adequate land raised concerns about ill-health that denies them the necessary strength to cultivate a wide range of crops. Inevitably, they opt for crops perceived as less demanding in terms of labour and other kinds of physical attention. During the survey cases of uncultivated land were reported by the farmers and attributed that to poor health especially HIV/AIDS related ailments. The country's estimated HIV/AIDS prevalence rate of about 25% and the reported cases of uncultivated farmlands have been viewed as part of its devastating impacts on agricultural production (Central Statistical Office (CSO) Swaziland & Macro International Inc., 2008).

Swaziland continues to receive mostly below normal rainfall with other years being said to be dry and drought is universally viewed as a paramount limiting factor to crop cultivation (UNEP, 2000, Nielsen *et.al,* 2005; USAID & FEWS NET, 2012). The sensitivity of crop selection to climate condition has been widely reported in Africa (Jose, 2003; Nielsen *et.al,* 2005; Kurukulasuriya and Mendelson, 2006; Biello, 2011). Crop selection is actually viewed as an adaptation strategy by farmers to overcome impacts of climate change characterised by high rainfall and temperature fluctuations (Rosenzweig and Parry, 1994; Gbatibou and Hassan, 2005; Kurukulasuriya and Mendelson, 2006.) The expectation is that as temperature rises and rainfall decreases farmers would opt for heat and drought tolerant crops inherently to reduce damages from climate change. Such an adaptation strategy is crucial on major grains like maize which are highly vulnerable to the unreliable and inadequate precipitation in sub-Saharan Africa (Gbatibou and Hassan, 2005). Therefore, one anticipated that the prevailing drought at Shewula would spur the farmers to select drought resistant crops such as sorghum or millet as these crops are normally preferred ahead of maize where annual rainfall is below 700mm (UNEP, 2000; Nielsen *et.al,* 2005; Rouanet, 2009). However, this was not the case at Shewula as the farmers continue cultivating maize despite the fact that the area continues to receive annual rainfall amounts less than 700mm for the past decade (2000-2010) (Rouanet, 2009). Selection of drought resistant crops such as sorghum would have clearly demonstrated the influence of the climate factor in the selection of crops by farmers at Shewula. However, the continued cultivation of maize clearly places the customary preference for maize (as the main source carbohydrates instead of sorghum and millet) ahead of the prevailing drought. Hence the farmers continue cultivating maize even during the prevailing drought while sorghum is cultivated on a small scale mainly for social reasons like brewing *umcombotsi,* a traditional beer.

3.5 CONCLUSION

The study established that the farming activity is dominated by women mainly because of the absence of men. The farming landscape is characterised by mainly rain fed subsistence farming carried out relatively small landholdings. In part this was a limiting factor to the selection of crops for cultivation as the range of crops cultivated by the farmers was found to be small. To a large extent farmers at Shewula cultivate traditional food crops for domestic consumption. The prevalent crop cultivation pattern is intercropping and it far outstrips monoculture. The prevalence of intercropping, as one of the basic tenets of CA, increases the prospects of adoption of CA as introduced by the current government in 2000. Maize, being a staple food in Swaziland, emerged as a very significance crop in the lives of the local farmers hence its continued cultivation despite the prevailing and persistent current drought that affects its production. Since the farmers demonstrated a long history of cultivating traditional crops and it may be concluded that prospects of the introduction of CA at Shewula, especially its thrust to promote the cultivation of traditional crops, may be brighter. The minimum or no tillage aspect of CA which, among other things, conserves soil moisture in dry conditions is complemented by selection of traditional crops that are tolerant to drought and pests (Russell, 1996; Nielsen, *et. al.,* 2005). Intercropping on the hand ensures crop production sustainability under adverse soil and climatic conditions (Rouanet, 1984).

It must be noted that the selection of crops for cultivation is not be a simple process that can be ascertained with any degree of accuracy. Rules or criteria guiding crop selection are complex and may vary from one situation to another. For instance, in Western countries crop selection is based on highly technical quantitative water use/yield models, cost-benefit analysis, soil nutrient demand, the cropping pattern (mono cropping or mixing of crops), and other related factors (Singer, *et.al.,* 2006). Traditional subsistence farmers, on their part, demonstrate reliance on traditional knowledge and systems at play as well as their individual perception of prevailing socio-economic and biophysical (environmental) conditions in the selection of crops to cultivate. Such factors include lack of financial resources due to prevailing poverty; lack of access to adequate farming land due to inequitable distribution of land common in areas under traditional authority like the SNL; and ill-health attributed mainly to rampant HIV/AIDS prevalence in the country. The influence of drought, which is attributed to climate change, cannot be downplayed the cultivation of crops in the country (Manyatsi, *et.al. 2010)*.

The study has demonstrated that in situations where there are inadequate agricultural research institutions the reliance on individual's intuition in crop selection prevails. This does not happen in Western countries because farmers are given guidance on crops to cultivate by existing state institutions as well as early warning support systems (Jose, 2003). In the final analysis the existence of many factors guiding selection of crops for cultivation cannot be revealed by the current study based on a small settlement in Swaziland. Nevertheless, it was established that the factors are not operating in isolation of one another but are interlinked in a complex way. Many interlinked factors guiding selection of crops for cultivation have been identified including crop storage methods, the plant part is used for consumption, threshing and crop's drying methods, land treatment, size of seed, traditional beliefs as well as resistance to drought, weeds, diseases prevalence (Cowlin, *pre* 2007; Cromwell and van Oosternhout, 2000).

Prospects of success of the project of introducing CA at Shewula are promising. This assertion is based on the prevalence of cultivation of traditional crops among the farmers which was the central thrust of the project. Moreover, the farmers are other basic tenets of CA especially intercropping. The nature of the factors guiding selection of crops for cultivation and those constraining cultivation of other preferred crops are among those that are either promoted or addressed by practice of CA. For instance the problem of lack of financial resources and ill-health are addressed by CA through the minimum or zero tillage principle that reduces farming costs and labour requirements especially for soil tillage. Moreover, the problem of drought is addressed by the accumulation of crop residue on the soil surface that prevents loss of soil moisture through evaporation, surface and wind. However, have the challenge to intensify the cultivation of proven drought resistant crops such as sorghum and cassava as they are currently cultivated by fewer farmers compared to maize. Farmers also need to diversify their crop selection to include other carbohydrates laden crops such as potatoes that have a higher yielding capacity.

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CHAPTER 4

THE LEVEL AND PATTERN OF ADOPTION OF CONSERVATION AGRICULTURE AT SHEWULA IN SWAZILAND

4.1 INTRODUCTION

Swaziland has an agro-based economy where agriculture supports the livelihoods of more 70% of the population (Forsyth-Thompson, 2011; FAO, 2013). Crop production, especially on Swazi Nation Land (SNL) is commonly practiced under rain fed conditions through soil tillage and is predominantly for subsistence purposes characterized by minimum capital and technological inputs. SNL is communal land under traditional authority where the Swazi people access land through traditional means, commonly accepted cultural forms of tribute, and enjoy user rights without legal title to land. On Title Deed Land (TDL) there is large-scale commercial farming under both rain fed and irrigation conditions characterized by huge capital and technological inputs. In the 1980s the country had a productive agricultural sector as the country was a net exporter of food especially maize (national stable food). National maize production was more than 100,000 metric tonnes annually exceeding national domestic requirement which was estimated at less than 90,000 metric tonnes per year (IRIN, 2012; FAO, 2013). Since then maize production has been variable over the years but with a downward trend (Smith, 2003; Sargeant, 2003; Riddell & Manyatsi, 2003; Edje & Mavimbela, 2005; FAO, 2013). For instance, after 2000 maize yields persistently declined to an annual average of about 70,000 metric tonnes while domestic maize requirements have increased to about 115,000 metric tonnes in 2011 (Swaziland Vulnerability Assessment Committee, 2010; IRIN, 2012). Therefore, about 11% of the Swazi population is experiencing annual food shortages which are normally addressed by annual maize imports where about 60% of the maize is acquired from South Africa (Mashinini *et. al.,* 2005; Swaziland Vulnerability Assessment Committee, 2010).

In its current state the country's agricultural sector is regarded to be in serious crisis as the country is failing to achieve its food security objective (Mashinini *et. al.,* 2005). This situation is attributed predominantly to the prevailing negative impacts of climate change (Oseni & Masarirambi, 2011). Since the late 1980s Swaziland experiences irregular and below normal rainfall that resulted in adverse impacts on agricultural crop production, particularly maize (USAID & FEWS NET, 2012). Moreover, the persistent drought also resulted in death of livestock basically reducing farmers' access to animal traction for soil tillage and adversely affected subsistence crop farming. The climate factor posed some formidable questions on the effectiveness and continued practice of conventional farming (CF) systems by the subsistence farmers in Swaziland. Costs of soil tillage and other CF practices are proving to be unaffordable to subsistence farmers under the prevailing circumstances which also include limited access to financial resources for inputs and labour. The prevalence of HIV/AIDS, estimated at 25% of the population, has also resulted in the loss of both human and financial capital crucial for agricultural development (Central Statistical Office (CSO) Swaziland & Macro International Inc., 2008). Overall, climate change and the persistent drought in particular have proved CF systems to be costly, less productive and at times inappropriate to subsistence farmers as it exposes people and land to threats of prolonged hunger and degradation (Mlipha, 2010). About 70 % of drought prone areas in Swaziland are severely degraded (SBSTTA, 1990; Government of Swaziland, 2012). Moreover, drought prone areas on SNL are perceived as low potential areas (LPAs) and therefore receive relatively less attention in terms of investment which appears to be biased towards irrigated and high potential rain-fed agricultural areas. This state of affairs precipitated the government's move to introduce new or alternative farming techniques in Swaziland. Ideally, new farming techniques offer opportunities to increase food production among developing countries (Feder *et.al.,* 1985). On the implementation aspect, the country embraced CA since 2000 which was introduced through the FAO Project on "Awareness Creation of CA" (FAO, 2000). In Swaziland CA entails minimum soil disturbance mainly through zero tillage while adhering to other fundamental principles of the system which include permanent soil cover by retention of crop residue as well as cultivation of a variety of crops in the practice of intercropping and crop rotation (FAO, 2011a; Hobbs *et. al.,* 2008; FAO, 2008). CA is essential for soil and water conservation while building a stable structure for sustainable crop production and crop diversity (Dumanski *et. al., 2006;* FAO, 2008; Williams, 2008).

The zero tillage and retention of crop residue were the most appealing features of CA to the Government of Swaziland due to inherent reduced labour and input costs as well as conservation of soil moisture, control soil erosion, improvement of soil organic matter content and protection of biodiversity (Fowler, 1999; Kemper & Derpsch, 1981; Dumanski *et.al*., 2006). CA allows farmers to achieve sustainable food production without adverse impacts on the land resources (FAO, 2008). The benefits of CA are realized in countries with higher adoption rates of the system such as the USA and Brazil. The level of adoption of CA was the main concern of the research as it sought to establish the extent to which the system has been adopted at Shewula in Swaziland since its introduction in 2000. Shewula, in the Lubombo administrative region of Swaziland, is one of the four pilot areas where CA was introduced in 2000. Other pilot areas are distributed in the other three administrative regions in the country including Kabhoke in the Shiselweni region, Luve in Manzini and Motjane in Hhohho.

The spread of CA in sub-Saharan African regions is well documented but there are few details about the specific pattern the adoption process followed in each country. Available literature report, predominantly, on factors facilitating or constraining adoption of the system with less country specific literature on the pattern the adoption process followed. Hence the research focused on ascertaining the basic patterns of adoption of CA in Swaziland based on the experience of Shewula. It is assumed that the time since the advent of the system in Swaziland has a bearing on its adoption level. The adoption process itself is assumed to follow socio-economic and general spatial patterns (Hagget, 2001; Diederen *et. al.,* 2003a; Diederen *et. al.,* 2003b). The theory of diffusion of innovation views the process of adoption of innovation as a mental one through which an individual farmer passes from an initial stage of encounter (hearing about) with an innovation to its final adoption (Hagget, 2001). Normally, very few farmers adopt a new farming system or technique on its advent. Rogers (1995) observed a slow start in the adoption of innovation (16% of early adopters) and the rate of adoption increases with time as the majority (68%) adopt the innovation until it is common to every farmer. Thereafter, a small group of farmers (16%), referred to as laggards adopt innovation very late (Hagget, 2001; Knowles & Wareing, 1976).

It was of interest to the study to establish the level and stage of adoption of CA at Shewula in Swaziland learning from Rogers' theory of diffusion of innovation. A spatial pattern of adoption of innovation is assumed to exist owing to the fact that the probability for spread of innovation is related to the distance between the source and destination of innovation (Haggett, 2001). The spread is stronger when the distance between the source and recipient of innovation is shorter than when it is longer (Haggett, 2001). In the case of adoption of CA at Shewula one notes the presence of trained farmers who besides being early adopters, they also act as local *foci* of the conservation agricultural innovation. Therefore, it was assumed that farmers located closer to those trained in the system would be more likely to adopt CA compared to those located further. Moreover, the closer location allows farmers to develop innovations in cooperation with the earlier adopters thus increasing their chances to adopt a new innovation (Diederen *et. al.,* 2003a). However, the study did not venture into ascertaining specific distance relationships as well as probable fields of contact among the farmers along the lines of Häggerstrand's (1968) mean information field (MIF). To be noted is that CA in Latin American countries and the USA was adopted largely by large-scale commercial farmers yet in Africa it is mainly introduced to non-commercial small scale farmers (Derpsch, 2005a). In Swaziland the introduction of CA is targeted at small scale subsistence farmers (FAO, 2000).

4.2 DESCRIPTION OF SHEWULA

Shewula is located within the Lubombo physiographic region on the northern-eastern part of Swaziland and is perched on the Lubombo plateau at about 300 – 500 metres above sea level. It is one of the four pilot areas for the introduction of CA in Swaziland which benefited from the establishment of three CA demonstration plots refered to Testing and Validation Units (Figure 4.1). Shewula is classified as one of dryland areas in the country with a dry sub-humid climate with a potential annual rainfall not exceeding 850mm per year (Government of Swaziland, 2012). Often the rainfall received is lower amid persistent drought spells experienced since 1990. The drought has significance impacts on the production of food crops such as maize at Shewula. The mean annual temperature is about 21^{o}C with a mean summer temperature of 26^{o}C and mean winter temperature of 17^{o}C (Government of Swaziland, 2012). Shewula lies within the foot and mouth disease quarantine area which constraints prompt disposal (sale) of livestock in times of need. This has resulted in relatively small livestock numbers in the area (Mlipha, 2004).

Shewula is inhabited by about 10 000 people of which 80% rely on subsistence farming. The remainder is engaged in wage employment in the neighbouring sugar-cane plantations and private farms. The community relies mainly on rain fed subsistence farming augmented by limited range of non-food income earning activities such as the conservancy facility (a community trust) which is run as a business venture to benefit the community in terms of employment and income. The area regularly qualifies for emergency food distributions which may result in dependency on the foreign donations. Maize being a staple crop is cultivated on a wide scale under rain fed conditions however the yields are continuously declining due to several factors including the area being drought prone, lack of cattle (for animal traction), shortage of tractors for hire, limited access to agricultural inputs and others (SCF, 1998; Mlipha, 2010). There is a variety of crops cultivated by the farmers at Shewula and the most dominant crop is maize as well as several other traditional crops albeit on a small subsistence scale (Chapter 3 above).

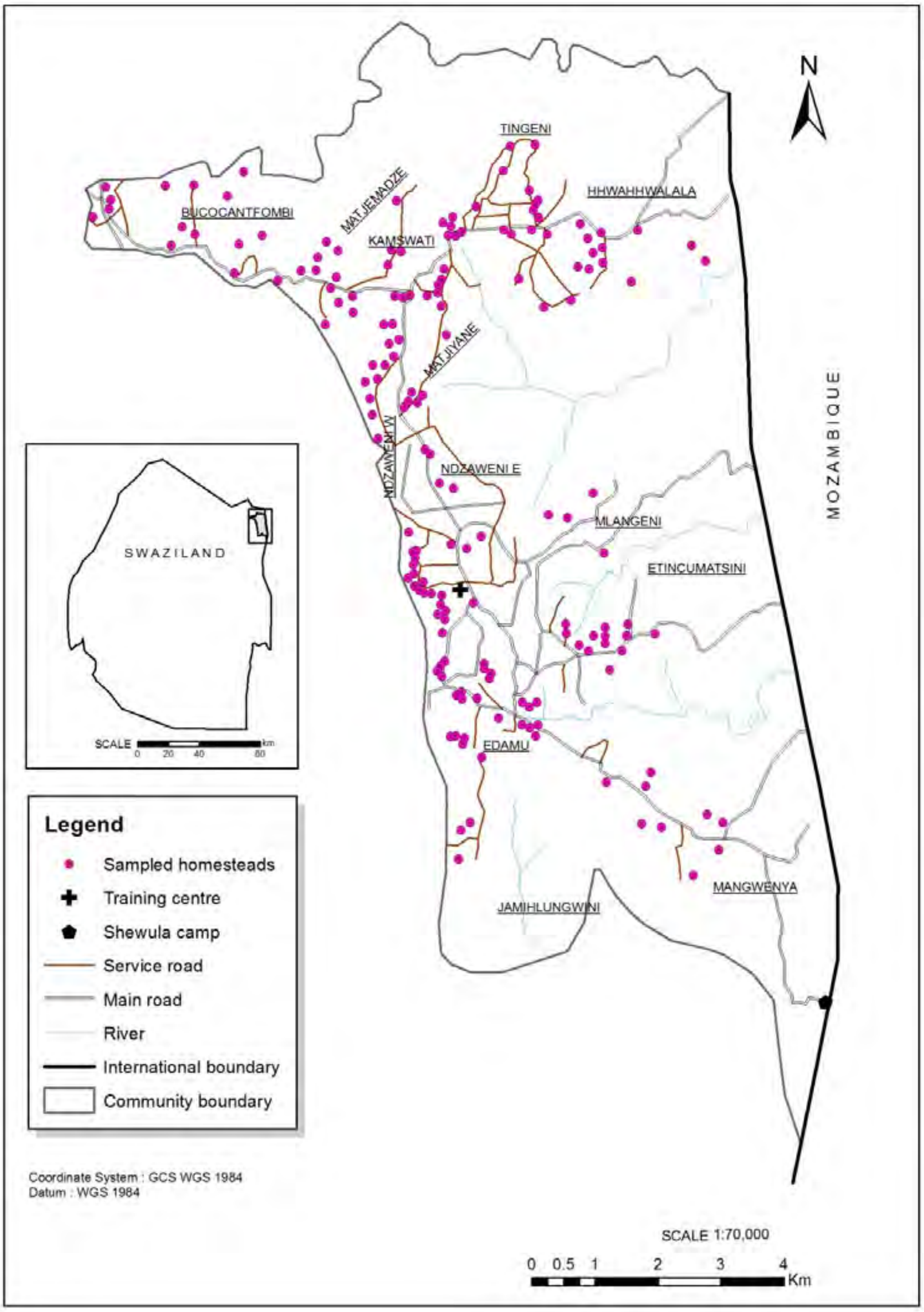

Figure 4.1 Map of Shewula chiefdom showing the distribution of homesteads sampled

4.3 METHODOLOGY

Primary data was collected through survey conducted by trained research assistants through face-to-face interviews. The questionnaire contained mostly closed ended items soliciting demographic data and farming details. There were also open ended questions soliciting respondents' opinions on the introduction and adoption of CA (Appendix B and C). The survey involved a sample of 313 respondents (farmers) representing one third (about 33%) of a total of about 940 homesteads. Respondents were selected irrespective gender or farming system they pursued and identified from homestead registers acquired from community sub-heads (*Bosigodzi*). The list had farmers' names in alphabetical order and assigned numbers. Systematic random sampling was used to select the respondents. Systematic random sampling is an equal probability method where the population is arranged according to a list and every n^{th} element in the list is selected after the first element has been selected randomly (Castillo, 2009). In this study the first homestead was selected using enumerator values drawn from a table of random numbers and thereafter every 3^{rd} homestead was selected for inclusion in the sample. The identities of the respondents and data acquired from them were obscured in accordance with ethical principles and considerations in research.

To complement the survey, two focus group discussions (FDGs) composed of 10 farmers each were constituted along the two prevailing farming systems *i.e.* conservation agriculture and conventional farming mainly to maintain fundamental homogeneity in the groups. Striving for homogeneity in the constitution and selection of FGD members is very significant to achieve consistency in the understanding of issues and contexts of deliberations (Owen & Jones, 1990). In addition to using the types of farming systems practiced by the farmers, the selection of members of the FGDs also considered gender balance where possible as well as representation of the subareas of Shewula. However, the selection system did not really guarantee equal gender representation in the FDG but two members of the FGDs were selected from each of the 10 subareas; one practicing CA and the other practicing CF. The list of homesteads acquired from the community sub-heads (*Bosigodzi)* were used again to select members of the FGD especially for those practicing conventional farming. A table of random numbers was used to select a name of a farmer in each of the sub-areas for inclusion in the FGD for farmers practicing conventional farming. There were fewer farmers practicing CA hence, the selection process was less rigorous. Therefore, volunteers practicing CA were asked to participate in the FDG through head hunting with the assistance of the FAO CA coordinator stationed at Shewula. The inclusion of all the subareas in the FGDs was not achieved as some subareas did not have farmers practicing CA at all while some had more than one farmer practicing the system.

The FGDs were conducted in the format of a meeting and covered topics dealt with how the farmers understood CA as well as factors influencing and constraining adoption of CA at Shewula (Appendix D). The topics were presented as agenda items and before the discussions, commenced the topics were put for approval by the members of the FGDs in their separate meetings. Names of members of the FGDs were deliberately concealed to protect their identities consistent with ethical research dictates.

Other special tools were used mainly to determine the spatial pattern of adoption of conservation agriculture at Shewula. These include the use of GPS devices to acquire data to portray the distribution of farmers according to categories such as those that have adopted CA, willing to adopt CA and not willing to adopt CA. Moreover, ESRI ArcGIS v10 and Google Earth were used for production of the map indicating the pattern of adoption of CA. SPSS v20 spread sheet was used for data input for further presentation and analyses. To a large extent data analysis and presentation involved basic descriptive statistics.

4.4 RESULTS

4.4.1 Demographic characteristics of the farmers

Only three basic demographic features deemed significant were considered in the study namely age, gender and education level. The study did not consider marital status and others socio-economic features such as income, occupation and others due to difficulties envisaged in their collection and ascertaining their influence in the adoption of CA. However, the influences of some of the omitted socio-economic factors are well documented in other CA literature (Diederen *et. al.,* 2003a; Diederen *et. al.,* 2003b)

4.4.1.1 Ages and gender of farmers at Shewula

The age composition of farmers at Shewula ranges from 20 years to above 60 years old. While slightly more than 40% of the farmers are below 40 years old there is a significant proportion of about 20% aged 60 years and above (Table 4.1). Table 4.1 below also indicates a strong dominance of female farmers accounting for more than 70% of all the farmers. Other studies have estimated the proportion of female farmers to about 80% (Mlipha 2010). It must be noted that the differences between the studies are due to differences in sample sizes. The current study was based on a larger sample of about 33% of the total population than the one noted above which was based on a 10% sample size. It must also be noted that the larger proportion of female farmers could be attributed to the fact that some female farmers are actually acting on delegated responsibility from their male spouses who were absent from their homesteads during the survey for various reasons.

Table 4.1 Ages and gender of subsistence farmers at Shewula

Age groups (years)	Gender of farmers				Total no. of farmers	% of farmers
	No. of females	% of farmers	No. of males	% of farmers		
20-29	50	16.0	13	4.2	63	20.1
30-39	53	16.9	13	4.2	66	21.1
40-49	59	18.8	18	5.8	77	24.6
50-59	26	8.3	18	5.8	44	14.1
60+	40	12.8	23	7.2	63	20.1
Total	**228**	**72.8**	**85**	**27.2**	**313**	***100.0**

* The use of mean and standard deviation would have been preferred statistics but respondents only gave age ranges.

4.4.1.2 Education levels of farmers at Shewula

More than half of the farmers lacked formal education and about 28% acquired primary school education. Only 19% of the farmers acquired post primary school with only 1% acquired tertiary education (Figure 4.2). The results indicate a grim literacy picture at Shewula that is far lower than the national rate of about 70% of the adult (15 years and above) population (World Bank, 2010; UNICEF, 2011).

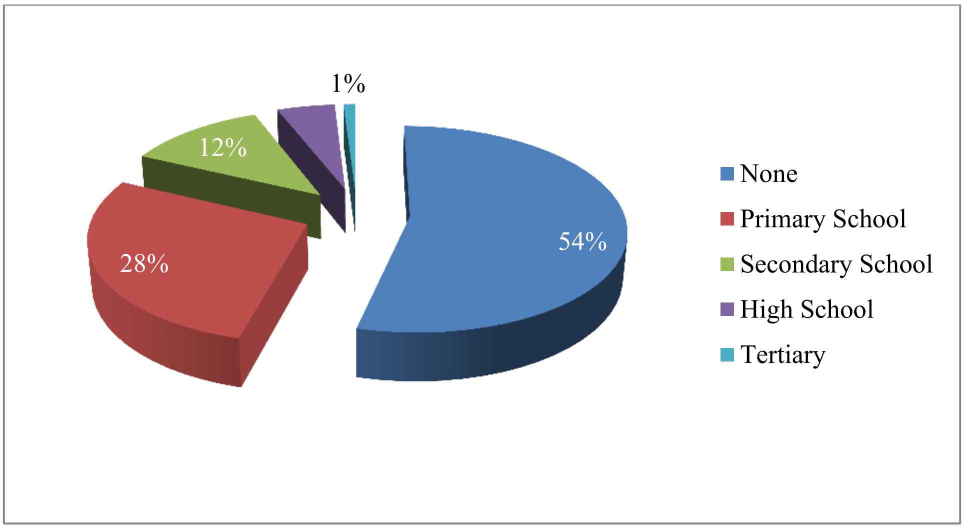

Figure 4.2 Level of education of subsistence farmers at Shewula

4.4.2 Level of adoption of conservation agriculture at Shewula

CA was introduced in 2000 and the first adoption of the system at Shewula occurred in 2003. From the sample, 5 farmers adopted CA in 2003; 2 farmers in 2004; 4 farmers in 2005 and 4 farmers after 2006. The questionnaire data did not reveal any adoption after 2006 and 2010. It is assumed that adoption did not stop in the years between 2006 and 2010 but continued in the population outside the sample. However, prior to 2006 the adoption rate was about 3.75 farmers per year and this adoption is anticipated to have continued taking into account the large proportion (65.5%) of farmers willing to adopt the system (Figure 4.3). Figure 3 below shows that only 4.8% of the farmers adopted CA by 2010. The rest were either willing to adopt (65.5%) or not willing to adopt (29.7%) CA. Farmers in both focus groups were unanimous that many farmers at Shewula wanted to adopt CA which indicates likelihood for the proportion of farmers adopting conservation to increase in the period after 2010.

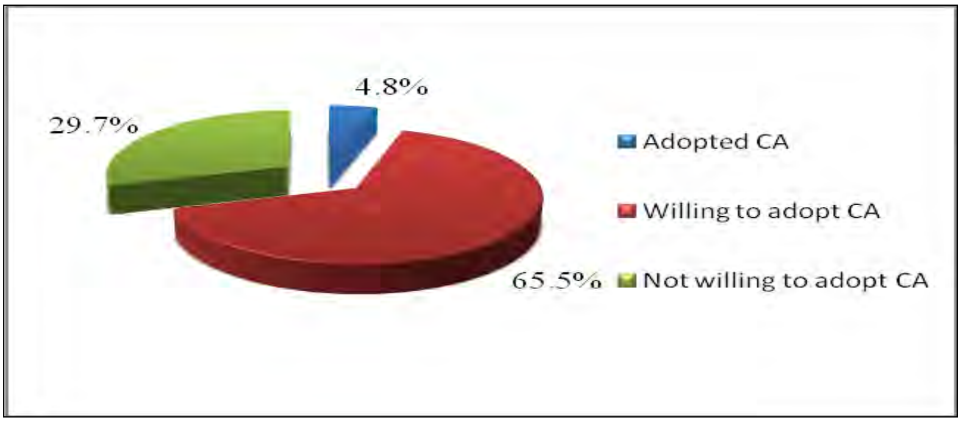

Figure 4.3 Level of adoption of conservation agriculture at Shewula, 2010

4.4.3 Demographic patterns of adoption of conservation agriculture at Shewula

4.4.3.1 Ages of farmers and level of adoption of conservation agriculture

Adoption of CA is concentrated among farmers aged between 30 and 59 years. These farmers are mostly exposed to informal community education and training activities which are the major platform for introduction of CA to subsistence farmers on SNL areas. The adoption level is significantly higher in the 50 – 59 years age-group where 13.6% of the farmers have adopted the system representing almost 2.0% of all the farmers (Figure 4.4). Figure 4.4 below also indicates an equal proportion of adoption levels in the 40 – 49 years age-group though the proportion of adopting farmers in the age-group is lower. Adoption is quite low in the 30 – 39 years age group as it accounts for only about 4.0% of farmers in the age-group and about 1.0% of all the farmers. None of the farmers in the age groups of 20-29 years and 60 years and above adopted CA at Shewula. The low adoption levels were not anticipated among the local young farmers since in other countries adoption levels of new farming practices were found to be higher among the young and educated farmers than older and less educated farmers (Diederen *et. al.,* 2003a). The lower adoption rates could be attributed to the prevailing mind-set rooted on CF techniques as well as negative perceptions of conservation agricultural practices created and reinforced by national formal agricultural education and training programmes which at the time focussed on promotion of CF practices. Older farmers, on their part, tend to be less educated and more conservative in their approach to farming which makes them less likely to open up to new farming innovations hence none adopted CA techniques.

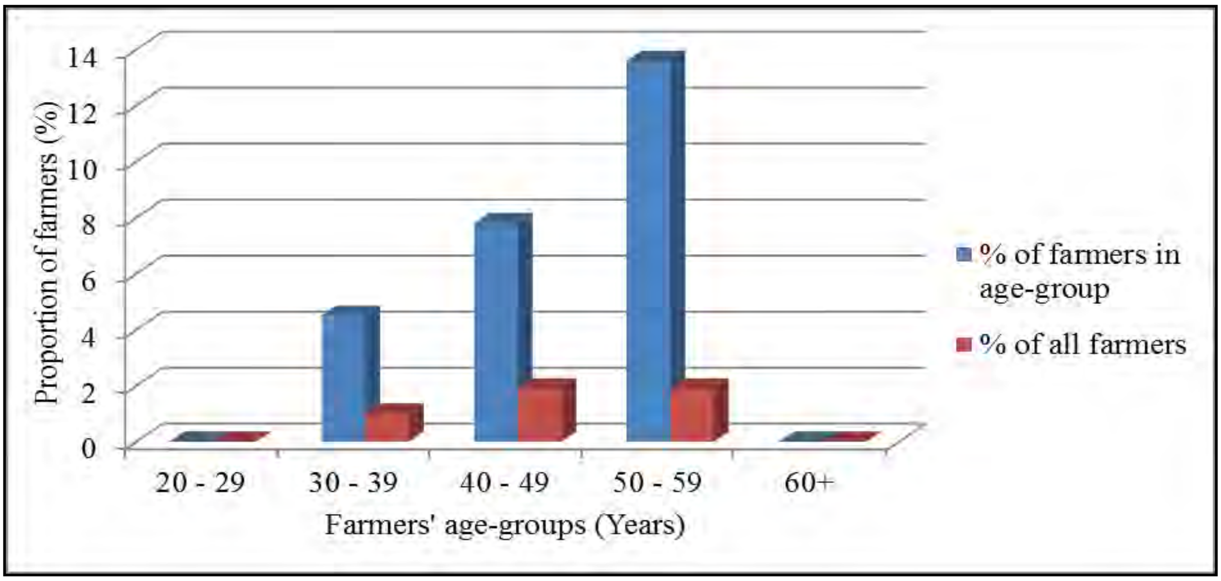

Figure 4.4 Farmers' ages and levels of conservation agriculture at Shewula, 2010

4.4.3.2 Gender of farmers and level of adoption of conservation agriculture

Female farmers that have adopted CA constitute 3.8% of the total sample and males account for only 1.0% (Table 4.2 figures in brackets). This shows that more female farmers adopted CA than males. Though females are more than males in the sample, however, 5.3% of females adopted the system compared to 3.6% of males (Table 4.2). Although variance between the two figures is low at 1.7 but it more or less portray differences in the adoption levels between males and female farmers. In other words despite the fact that female farmers are more than males the relative proportion of female farmers adopting conservation farming is still higher than that of male farmers.

Table 4.2 Gender of the farmers according to types of farming systems they practice

Types of farming	**Gender**				
	Females	**% of females**	**Males**	**% of males**	**Total** (% total)
CA	**12**	**5.3** [1](3.8)	**3**	**3.6** (1.0)	**15** (4.8)
CF	216	94.7 (69.0)	82	96.4 (26.2)	298 (95.2)
Total	**228**	**100.0** (72.8)	**85**	**100** (27.2)	**313** (100.0)

[1] All the figures in brackets denote percentages based on total sample.

4.4.4 Farmers' education levels and adoption of conservation agriculture

The results reveal that adoption of CA is higher among farmers with formal education and lower among farmers without formal education. A majority of the farmers 169 or 54% do not have formal education and only about 2% (4) of those farmers adopted CA. The adoption level is relatively higher among farmers with formal education especially with primary and secondary school education where 7.9% and 8.1% of the farmers have adopted CA respectively. . The proportion of farmers practicing CA is also significant among farmers with high school education where 6.3% of the farmers have adopted CA. Relative to farmers in all the education levels it emerges that farmers without formal education and those with tertiary education are the least adopters of CA at Shewula (Figure 4.5). Focus groups mentioned that most of the old farmers did have the opportunity to attend formal schools and a majority are illiterate whereas most of the young farmers have high school education and a few with tertiary education. Notably in Figure 4.4 above there was no adoption among the young and older farmers. Likewise, in Figure 4.5 below relatively low adoption levels are portrayed among farmers with no formal education and those with tertiary education which happen to be dominated by the older and younger farmers respectively. The influence of education on adoption pattern of new farming techniques has been established in other countries though the situation pertaining to the local young farmers is to the contrary (Diederen *et. al.,* 2003a).

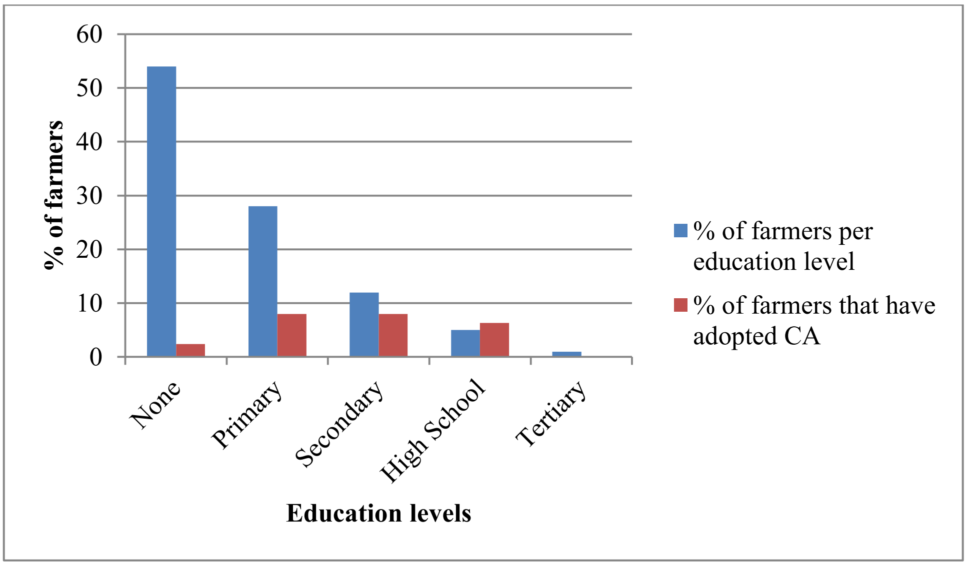

Figure 4.5 Percentage of farmers that have adopted conservation agriculture according to education level

4.4.5 Spatial pattern of adoption of conservation agriculture at Shewula

The spatial aspects considered in the study include the basic attributes of CA adopted, proportion of land farmers dedicated to CA and the general spatial distribution of farmers practicing the system in relation to those either willing to adopt the CA or not willing. A significant proportion (65.5%) of the farmers is willing to adopt CA and they far outweigh those who are not willing (Figure 4.3). It was of interest to establish the general spatial distribution of these farmers in relation to that practicing CA.

4.4.5.1 Level of adoption in relation to basic attributes of conservation agriculture

The basic attributes that were studied include minimum or zero tillage, intercropping and crop rotation, maintenance of soil cover (through accumulation of crop residue and cultivation of cover crops), direct seed planting into a water retention bowl and cultivation of indigenous crops. These attributes were derived from the FAO (2000) project introducing CA in Swaziland. Framers in the four pilot areas in Swaziland were actually trained on the practice of the mentioned key attributes of the system. Therefore, the findings of the survey and the CA focus group indicated that all the farmers practicing the system were applying all the attributes they were trained in as mentioned above. Some farming practices associated with CA, such as cultivation of indigenous crops and intercropping are prevalent at Shewula even among farmers not practicing (Chapter 3 above). Only the zero tillage and maintenance of soil cover were exclusive to farmers practicing CA.

4.4.5.2 Pattern of adoption in relation to proportion of land on conservation agriculture

Generally there was partial adoption of CA as none of the farmers practiced the system exclusively. In other words none of the farmers dedicated their entire farming land to CA; instead farmers practiced the system on varying proportions of their farming land for varying reasons (Table 4.3). Only one farmer was at an advanced stage of adopting CA having dedicated about 90% of farming land to the system and the farmer did not present any reason for not practicing the system in the entire farming land. About six farmers (40%) dedicated half of their farming land to CA and they cited lack of resources to fully convert to the system.

The critical resource people mentioned was finance to purchase relevant equipment and to fence off the land where CA was practiced to control livestock movement and trampling on soil as well as prevent them from consuming the crop residue that is crucial as soil cover in the system. Other farmers dedicated between 10% and 40% of their farming land to the system for reasons of maintaining a balance between the two farming systems while others were simply experimenting with the two systems to inform their future decisions on whether to adopt CA or not. One farmer who practice CA on 20% of farm land mentioned being interested to adopt the system to a greater extent but was constrained by commitment of 80% of farming land to a local maize growing scheme that encourages maize production under CF practices. The findings indicate critical areas of intervention to encourage adoption of the system in the country. The need for local experimental data to farmers is of great significance especially in facilitating decision making to adopt the system or otherwise. Moreover, financial support to farmers is crucial to enhance access to equipment and other material materials crucial for promotion of adoption of CA.

Table 4.3 Proportion of farming land dedicated to conservation agriculture and reasons for the partial adoption

% of land under CA	Number of farmers	Reasons for partial adoption
90	1	No reason but in a process to full conversion of cultivation to CA
50	6	Committed to CA but lack resources such as money to fence the rest of the land and convert it to CA.
40	3	Just maintaining a balance between the two systems for cushion in case one system fails.
30	3	Still experimenting on the costs and benefits of CA compared to CF
20	1	Already committed 80% of his land to the maize scheme practiced under CF. Otherwise have the desire to convert to CA.
10	1	Just experimenting to see how CA fairs compared to CF

4.4.5.3 Distribution of farmers according to status of adoption of conservation agriculture

Figure 4.6 below shows the distribution of farmers that have adopted CA in relation to those who indicated to be either willing to adopt CA and those who were not willing. A general descriptive spatial distribution pattern was used without specific and quantified distances separating the farmers practicing the system and those either willing to adopt the system and those not willing. The pattern that emerged indicates a sparse distribution of farmers practicing CA with more of them located in the northern part of Shewula within the Hhwahhwalala, Tingeni, KaMswati and Ndzaweni. For some reasons unknown to the researcher initial training of farmers on CA concentrated on this part of Shewula. Moreover, the CA resource centre was established at Ndzaweni while two of the area's three testing and validation units (TaVUs) are located at Hhwahhwalala and Ndzaweni. TaVUs are experimental plots on CA used for demonstration purposes during training of farmers. A few of the farmers who have adopted the system were found at Bococantfombi where the third TaVU is located.

The other spatial pattern that emerged is the tendency for farmers willing to adopt CA to cluster in closer proximity to those that have adopted the system than those not willing to adopt the system. The focus groups revealed that farmers willing to adopt the system were mainly influenced by those practicing the system. It was reported that farmers practicing CA periodically conduct training and demonstrations on the system targeted mainly at their neighbours. The farmers not willing to adopt CA were located relatively further than those practicing the system. Therefore, it is apparent that the farmers practicing CA can play a pivotal role in influencing the adoption of CA. Therefore, there is a need to capacitate them with resources and information relevant for training their fellow farmers to adopt the system. Moreover, subsequent research is critical to ascertain specific distance relations of the distribution farmers portrayed in Figure 4.6 below using various quantitative methods such as the nearest neighbour analysis, cluster analysis to name but a few.

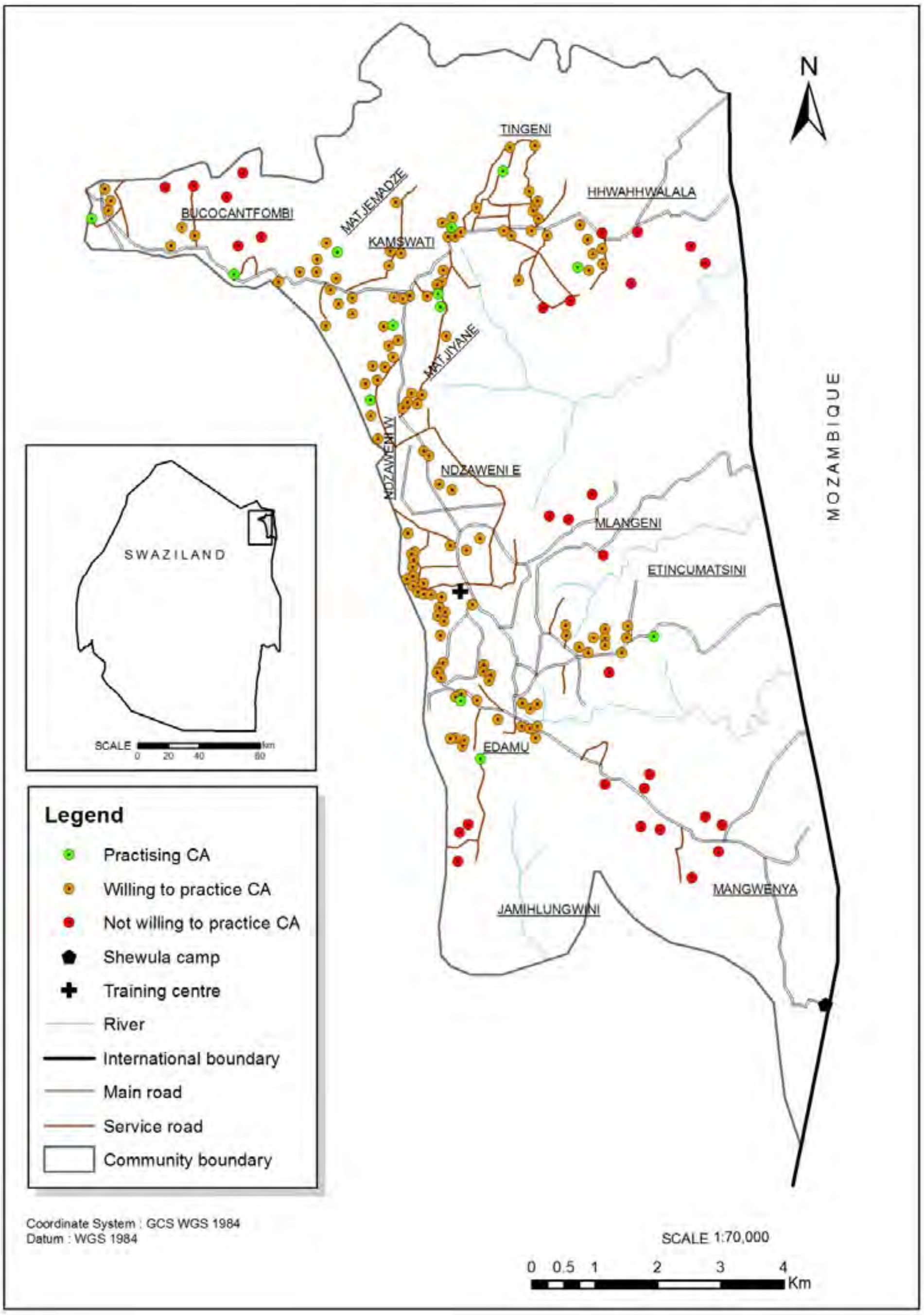

Figure 4.6 Map of Shewula showing the general spatial distribution of farmers practicing conservation in relation to those willing and not willing to adopt conservation agriculture

4.4.6 Status of awareness of conservation agriculture among farmers

The status of awareness of CA was established through ascertaining the farmers' understanding of the key features of the system based on information acquired from the two focus groups. Farmers in both focus groups were required to rank the top five key features of CA known to them. The focus group for farmers practicing CA regarded no soil tillage as the number one feature describing the system and proceeded to list the other features accurately. The focus group for farmers not practising CA ranked their "lack of knowledge" of the basic features of the system as number one. However, the features they ranked 2nd and 3rd were relevant in the description of CA yet features ranked 4th and 5th were not (Table 4.4). It seems the no till and retention crop of residue as soil cover were basic features known about CA that captured the understanding of both sets of farmers. The information in Table 4.4 below demonstrates differential levels of understanding of CA within the groups but not absolute lack of awareness.

Table 4.4 Basic features of conservation agriculture as ranked according to their importance by focus groups

Features presented by focus group of farmers practicing CA	Features presented by focus group of farmers not practising CA
1. No soil tillage	1. None known to farmers
2. Requires accumulation of crop residue	2. No tillage of soil
3. Cultivation of indigenous seeds/crops	3. No removal of crop residue
4. Direct planting and placing of fertilizers	4. System brought about NGOs
5. Use simple tools	5. System for hard workers

During the survey individual farmers were also required to mention just one basic feature of CA. Their responses indicate that 53.5% of the farmers did not know any of the basic features of CA (Figure 4.7). About 28% of farmers associated CA with no till while 6% associated it with retention of crop residue. However, 11% of the farmers viewed CA as involving both no till and retention of crop residue. These were the farmers with relatively better understanding of CA. The main implication is that awareness raising activities undertaken to date have only accessed about 46% of the farmers at Shewula and left out about 54% of the farmers. Awareness raising and training campaigns are still needed at Shewula to benefit the remaining half of the farmers without basic awareness and understanding of the system.

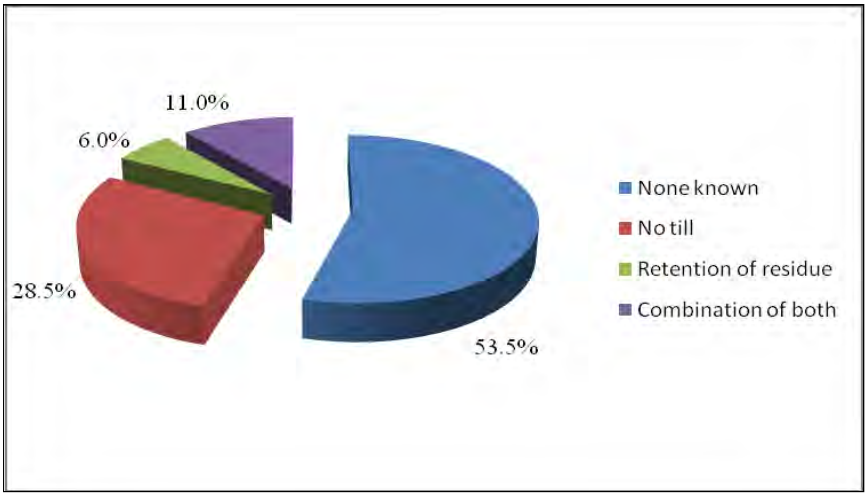

Figure 4.7 Proportion of farmers understanding basic features of conservation agriculture at Shewula

4.4.7 Motivation to adopt conservation agriculture

The focus groups were requested to list five factors that would motivate or motivated them to adopt CA according to order of importance. The focus group of farmers practicing CA ranked advantages or benefits derived from the system as the most important motivating factor. Subsequent motivating factors ranked 2nd, 3rd, 4th and 5th respectively included influence from NGOs; neighbours practicing the system; trainers of CA; and agricultural extension officers. The focus group of farmers not practicing CA ranked higher lack of motivating factors to adopt the system. However, they subsequently ranked the following 2nd, 3rd, 4th, and 5th respectively: available training opportunities; low financial inputs; higher yields than the conventional systems; and retention of soil fertility. These factors are not only similar to those mentioned by the focus group of farmers practicing CA but they are also fundamental advantages and benefits of adoption of the system. Table 4.5 below, therefore, shows that the factors motivating adoption of CA revolves around perceived advantages of the system.

Table 4.5 Factors motivating for the adoption of conservation agriculture at Shewula

FDG for farmers practicing CA	FDG for farmers not practising CA
1. Advantages and benefits of CA	1. Nothing motivating about CA known to farmers
2. Italians (NGO called COSPE)	2. Training opportunities on farming
3. Neighbours practising CA	3. Low financial input into farming
4. Trainers of CA	4. The higher yields observed from those practising CA
5. Agricultural extension officer (*Umlimisi*)	5. Retains soil fertility

The findings from the focus group correlates with responses from individual farmers pertaining to perceived advantages of CA in Figure 4.7 below. More than 60% of all the farmers mentioned various advantages associated with CA and slightly above 30% did not know any advantages of the system. Most of the farmers viewed higher yields as an advantage of CA while others found the system to be less expensive and recognise it for its encouragement of intercropping. A few of the farmers were of the perception that CA protects the soil from degradation and it is productive under drought conditions. Slightly over 20 of the farmers found the system to offer training opportunities which to them was an advantage of CA. However, more 100 farmers did not know any advantages of CA. The focus group of farmers practicing CA believed that the fertility of their soil has either been maintained or improved since they adopted the system. They attributed this to intercropping, decomposition of crop residue and planting of cover crops.

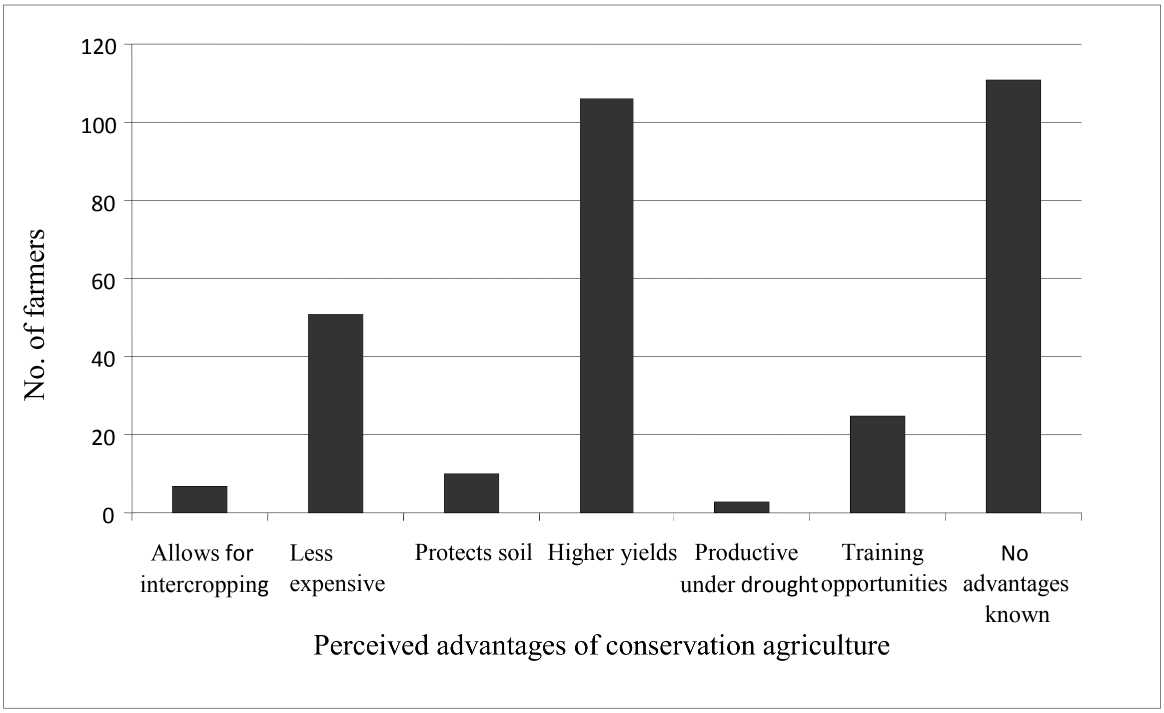

Figure 4.7 Perceive advantages of conservation agriculture

4.4.8 Reasons for not adopting conservation agriculture

Farmers not practicing CA were requested to state the reasons for their reluctance to adopt CA. Figure 4.8 indicates that a majority (88.3%) of the farmers mentioned lack of information about the system as the main reason for lack of adoption. Other farmers mentioned lack of appropriate tools for CA and the system being difficult to understand as reasons for reluctance to adopting it.

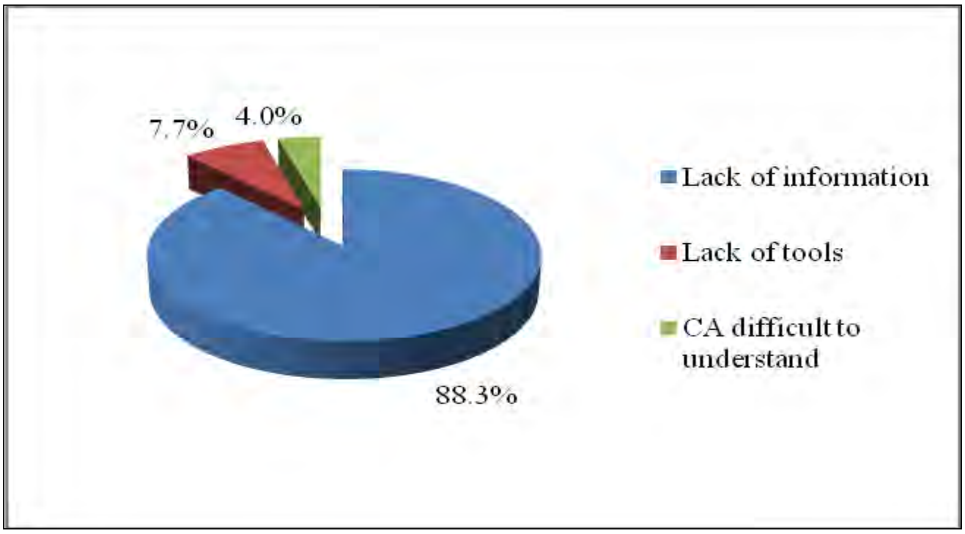

Figure 4.8 Reasons for not adopting conservation agriculture

However a majority of farmers regard the various disadvantages they associate with CA as major drawback towards its adoption. The perceived disadvantages of the system include increased incidence of weeds which was cited by more than 40% of the farmers. Other disadvantages mentioned include the system's high labour requirements and that it tends to harden the soil while others found it to be time consuming. Very few farmers associated CA with increased incidence of pests. Slightly above 25% of the farmers, which is a significant proportion, did not know any disadvantages of CA (Figure 4.9). This could be farmers that lacked knowledge and awareness about the system or those few who currently enjoy benefits of the system after adopting it. However, the farmers practicing CA mentioned that practicing the system is very demanding in terms of labour and time at the initial phases of adoption. But the labour requirement, in particular, sharply decreases with continuous practice of the system in the subsequent years.

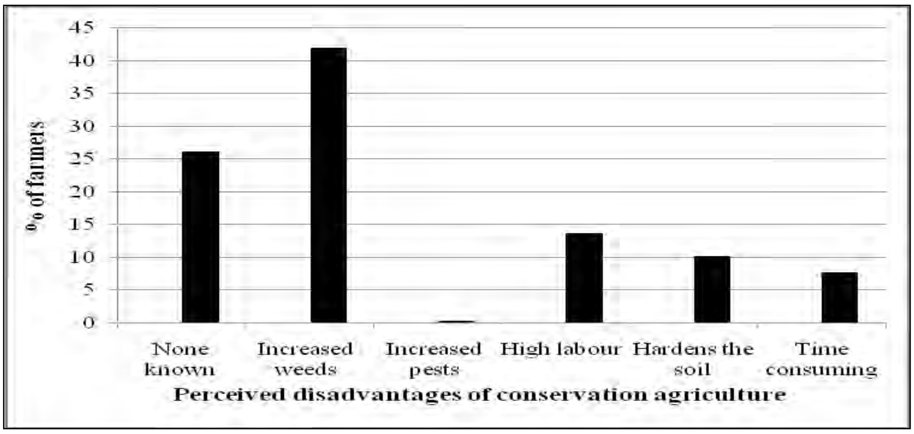

Figure 4.9 Perceived disadvantages of conservation agriculture

4.5 DISCUSSION

After more than 10 years of introduction of CA at Shewula only 4.8% of the farmers have adopted the system. Nationally, the adoption level may be even lower when taking into account that Shewula was at the forefront, as the first pilot area, in the introduction of the system in Swaziland in 2000. Low adoption levels of CA also prevail in many sub-Saharan Africa countries where the system is at its early stages of introduction (FAO, 2008a). The adoption status is also low in southern Africa where projections indicate that only 1% of arable land is under CA (Hove *et.al.* 2011).The observed slow start in the adoption of CA is a normal trend in the uptake of new farming technique by farmers according to Rogers' (1995) theory of diffusion of innovation. According to the theory only a few, about 16% of farmers adopt a new farming technique or innovation on its advent and thereafter a majority begin to adopt the innovation (Hagget, 2001; Knowles & Wareing, 1976). Rogers' theory does not give a precise timeframe for the initial adoption period making it difficult to establish if Shewula's initial 10 year period of adoption is adequate to use as bench mark to ascertain the adoption level of CA in the country. However, the 4.8% proportion of farmers who have adopted the system appears to be far lower than Rogers' 16% of early adopters. It seems it would take a period of about 35 years to have a proportion of early adopters of similar size to that in Rogers' theory if the prevailing local circumstances are maintained.

Theoretically, the adoption rate and levels are anticipated to pick up in the long run (Hagget, 2001). However, there is no timeframe for such to take place suffice to mention that in Brazil it took 15 years for CA to take-off at a reasonable rate of adoption after its introduction (Bafana, 2010). Encouraging scenarios supporting the anticipated increase of adoption of CA are noticeable in Africa especially in Zambia where an adoption level of about 10%, assumed to be one of the highest in Africa, was observed in 2006 (Baudron, *et. al.,* 2007). However, the main worrying factor with a potential to curtail significant adoption of CA at Shewula is the low level of awareness of the system among farmers. Slightly more than 50% of the farmers demonstrated lack of awareness of CA shown by their failure to state the key features of the system. Nevertheless, anticipated increase in the adoption of CA would occur if strategies are implemented to improve and sustain the current adoption level beyond the lifespan of projects facilitating the introduction and adoption of the system (Nkala *et. al.*, 2011; Baudron *et. al.,* 2011).

Explanations for the low adoption level of CA point towards the lack of awareness and basic knowledge of the system. Some basic elements of CA are familiar to local farmers particularly intercropping and creation of field ridges for maximum utility of water (Lado *et al*., 2005). However, the no tillage and retention of crop residue inherent in CA make the system appear unrealistic and difficult for the local farmers to comprehend. Farmers in Swaziland are grounded and groomed on soil tillage which is an integral feature of CF techniques hence the farmers failed to see logic in a farming system without tillage. Soil tillage is currently viewed as being crucial in the preparation of a "good" seedbed for planting seed as well as burying stubble to promote its decomposition and minimize weed and disease infestation of the previous crop (Fowler, 1990). Hence farmers tend to associate CA with various disadvantages and demonstrated skepticism about the success of the system once adopted. Actually the farmers at Shewula associated CA with increased weed infestation and high labour requirements. This was found to be the case with farmers in the Zambezi Valley who also cited the prevalence of weeds as inherent with CA and therefore one of the main reasons for their reluctance to adopt the system (Baudron *et. al.,* 2011). Prevalence of chronic illnesses especially those related to HIV/AIDS impacts negatively on availability of agricultural labour (FAO, 2006; World Vision Swaziland, 2010)). The bottleneck posed by labour requirement on CA was also noted in Zimbabwe and chronic illness, since it impacts negatively on labour availability for farming, was found to limit the uptake of the system among Zimbabwean farmers (Mazvimavi & Towmlow, 2009; Mazvimavi *et.al*, 2010). Swaziland is currently experiencing HIV/AIDS prevalence rate of about 25%, viewed as one of the highest in the world, which may be the basis for the farmers' negative perception of CA as far as labour requirement is concerned (Ministry of Health, 2011; Central Statistical Office (CSO) Swaziland & Macro International Inc., 2008).

Besides the influence of the perceived disadvantages associated with the system on the adoption of CA, the farmers also cited lack of information about the system as a factor that constrained uptake of the system at Shewula. Notably, in Lao the lack of information and detailed aspects about CA were responsible for low adoption level of the system by local farmers (Nanthavong *et.al,* 2011). Hence the importance of information generation and dissemination to farmers is a key ingredient to the uptake of new farming technology. Currently, there is insufficient locally generated information on CA accessible to the farmers in Swaziland (Mlipha, 2010; Dlamini & Masuku, 2011). In other African countries there has been an increase in research programmes on CA owing to its efficiency in other regions to combat soil erosion and improve crop yields (CGIAR, 2011). Availability of information played a key role in the adoption of CA among Latin American countries especially Brazil (Dumanski *et.al.* 2006; Derpsch & Friedrich, 2010). In Swaziland farmers are currently exposed to substantial information about CF techniques which continues to reinforce reliance on CF techniques to the disadvantage of adoption of CA. Hence, some farmers at Shewula regard CA as a difficult system to understand and practice.

Other farmers based their reluctance to adopt the system on lack of farm equipment appropriate for the system. Equipment currently at the disposal of the farmers, either in their possession or in the local market, is relevant for CF techniques. Therefore, there is reluctance among the farmers to change to a new system of farming thus rendering their equipment obsolete while going into expenses of procuring new types of equipment. To date farmers practicing CA use communal equipment on rotational basis and this is uncomfortable to some farmers who over the years have owned their individual equipment. Urgent initiatives to avail equipment appropriate for CA in the local market are needed while means are made to dispose obsolete equipment in a manner beneficial to farmers.

Factors motivating factors to adopt CA are largely grounded on the potential benefits of the system to the farmers and other advantages of the system perceived by the farmers. The farmers were unanimous that higher yields exerted the strongest influence on them to adopt CA. Even the farmers currently not practicing the system recognised the higher yields accruing to their neighbours practicing CA as an important advantage of the system of significant appeal to them. In Malawi 92% of farmers not practicing CA reacted with interest to the system having noticed benefits their neighbours derived from practicing the system (Williams, 2008). This highlights the significance of the benefits of CA and role of neighbouring farmers practicing the system in influencing individual farmers to adopt CA. At Shewula, farmers practicing CA conduct training and demonstration activities for purposes of informing their neighbours about the system. The farmer-to-farmer training strategy was very effective in the promotion of CA among countries in Latin America (Dumanski *et.al.* 2006).

Other motivation factors for adoption of CA at Shewula include training and extension opportunities as well as technical and financial support from government and non-governments organizations and agencies. At Shewula pioneering farmers received training by experts from Latin American countries with a long history of practicing CA. The training was supported by capacity enhancement among agricultural extension officers to assist farmers adopt and practice CA. Intensification of training and extension services often result in more farmers adopting innovation (Dierderen *et.al.* 2003; Nanthavong *et.al,* 2011). Actually increased extension visits increases the level and rate of adoption of CA (Tsegaye *et.al,* 2008). In Swaziland there are challenges in the provision of regular and frequent extension visits to farmers. The main challenges noted were the high extension officer to farmers' ratio as well as the dispersal nature of the country's rural settlements which require extension officers to travel long distances without vehicular support. Therefore, the effectiveness of extension services to facilitate adoption of CA is constrained.

The Government of Swaziland through, the Ministry of Agriculture, and non-government organizations and agencies such as COSPE (Co-operation for the Development of Emerging Countries) and FAO facilitated the introduction and adoption of CA in the country. This was through various means including provision of technical expertise as well as farm inputs and equipment as part of a project to support farmers during the process of introduction of CA (FAO, 2000). The project lasted for five years, from 2000 to 2005. Projects of this nature are a common feature in the introduction of CA among southern African countries (Mlamba, 2010; Mazvimavi *et.al,* 2010). However, their effectiveness is difficult to appreciate in view of the low levels of adoption noted above. Moreover, the projects are suspected to create perpetual dependency on project support among farmers adopting CA. The farmers often abandon practicing the system at the end of project implementation as it was the case in Zimbabwe where about 11% of the farmers receiving project support stopped practicing the system after the withdrawal of the support (Mazvimavi *et.al*, 2010). Could it be the case that a similar situation is unfolding at Shewula and in the country accounting for the low level and slow rate of adoption of CA especially after 2005? A year by year analysis of the level of adoption of the system since its introduction in 2000 to about 15 years after, involving a bigger sample may provide some answers to the question above.

A pattern of adoption of CA based on gender, age and education levels of farmers was noted at Shewula. Though adoption of CA is assumed to be “gender neutral” but it tends to be biased towards males during the introduction phase (Lubwana, 1999). Culture and traditional norms puts control of resources on males hence they end up at the forefront in making decisions to adopt new farming systems (Nanthavong *et. al.,* 2011). Table 4.2 above indicates that the proportion of female farmers who have adopted CA at Shewula in the first ten years of its introduction is higher than that of males. About 5.3% of all female farmers adopted CA compared to 3.5% of male farmers. However, the situation is reverse when it comes to CF. The gender perspective in the adoption of CA observed at Shewula is apparently contrary to situations obtaining in other parts of Africa where the proportion of male farmers adopting CA is larger compared to female farmers. This is attributed to gender inequality in the distribution of farmland in other parts of Africa where males tend to access larger tracts of land than females (Friedrich & Kassam, 2009; Lugandu, 2013). It has been observed that farmers with larger land holdings are more likely to adopt innovation compared to those with small land holdings (Perrin & Winkelmann, 1976). The latter, with limited size of land dedicate themselves to prevailing or known farming techniques to minimize risks. Yet farmers with larger land holdings use other portions of their land to try new farming techniques and look for new niches as well as demonstrating willingness to take risks. Hence more male farmers were found to dedicate more of their land to CA than females in some parts of Africa (Friedrich & Kassam, 2009).

The youngest and oldest farmers did not adopt CA at all at Shewula. Lack of adoption of new innovation is common among older farmers because of their low education levels which affect their ability to judge opportunities brought by innovation (Diederen *et. al.* 2002). Moreover, older farmers, due to their experience with existing farming techniques, take time to appreciate opportunities to innovate (Hove, *et.al.* 2011). For these farmers to adopt a new farming technique they have to consider the performance of current farming techniques and if they fell short of meeting their needs then a reason to adopt a new technique is realised. The opposite is true if the farming techniques are performing well. The lack of adoption of CA among the younger farmers at Shewula may be viewed as unusual since farmers in general are regarded to be more likely to adopt innovation in their youthful years (Diederen *et. a.*, 2003).

Levels of adoption of CA also differed according to education levels of the farmers at Shewula. More than 70% of the farmers practicing CA have attained at least primary education. Only 27% of the farmers without formal education adopted CA yet they constitute over 50% of all the farmers. The literacy rate of 54% at Shewula is far lower than the national rate of about 80% and the results show a low adoption rate among the farmers without formal education. This demonstrates that campaigns promoting adoption of CA need to focus on famers lacking formal education.

Spatial patterns of adoption of CA were also observed at Shewula. The farmers that practice CA at Shewula were found to be applying all the basic attributes of the systems including zero tillage, retention of crop residue, intercropping and crop rotation, cultivation of indigenous crops to name but a few. This is due guidelines on practice of the system given to farmers during training and demonstrations sessions that were undertaken during the introduction of the system in Swaziland. Moreover, technical support provided to adopting farmers ensured that all the basic attributes of the systems were applied. Application of some attributes of conservation was observed even among farmers involved in CF. Practices such as intercropping and cultivation of indigenous crops, commonly associated with the introduction of CA in the country, were prevalent among all farmers at Shewula. Based on this state of affairs one may raise the notion of widespread partial adoption or practice of CA in the area. That notion, however, is immediately disqualified by the non-practice of zero or minimum tillage and retention of crop residue which are widely regarded as fundamental for a farming system to qualify to be regarded as CA (Dumanski *et. al.,* 2006).

Partial adoption of the system was actually observed in the proportion of land adopting farmers committed to CA. Only one farmer adopted CA to significant proportion with 90% of farming land committed to the system. The average proportion of land the adopting farmers committed to CA was about 40% of total farm land. This proportion is slightly higher than the situation in other African countries where the average proportion of land committed to the system was from 10% to 20% of total farmland (Nkala *et. al.,* 2011). The adoption pattern observed at Shewula does not in any reflect higher adoption level of the system if the current percentage of farmers who have adopted the system is anything to go by. The small proportion of land committed to CA is believed to be an attempt by farmers to cushion themselves against impacts of drought since crop under cultivation CA is believed to yield even during drought (Nkala *et. al.,* 2011). However, this does not indicate the farmers' attempts to adopt the system in a sustained manner. In Swaziland, the partial adoption is a result of farmers either experimenting with the system or lacking resources requisite for the initial practice of the system which is regarded as demanding.

The distribution of farmers practicing conservation was found to be random and sparse with more of the farmers located in the northern parts of Shewula. As noted above, this part of Shewula is where the two CA demonstration plots (known as testing and evaluation units) are located. Likewise, a majority of the first adopters of the system are located in the northern parts of Shewula. An emerging general pattern of adoption depicts the clustering of farmers willing to adopt the CA closely around those already practicing the system. This was especially the case at KaMswati, Tingeni, Edamu and Hhwahhwalala. Farmers not willing to adopt the system were consistently located further than any of the farmers practicing CA. This was the case at Mlangane and Mangwenya where there was no farmer practicing CA (Figure 6). General spatial patterns of adoption of innovation always exist where the probability for spread of innovation is related to the distance between the source and destination of innovation (Haggett, 2001). According to Haggett (2001) the spread is stronger when the distance between the source and recipient of innovation is shorter than when it is longer. In the case of Shewula one must note the significance of the existence of farmers trained in CA and those already practicing the system in the spread of the CA innovation in the area. These farmers collectively act as the local source of the CA innovation. Therefore, it is assumed that farmers located closer to them would be more willing and likely to adopt the system than to those located further. Moreover, the close proximity or location of farmers allows them to develop innovations in cooperation with the earlier adopters thus increasing their chances to adopt new farming innovation (Diederen *et. al.,* 2003a). To a large extent Figure 6 above portrays that situation or pattern despite that the study did not venture into ascertaining specific distance relationships as well as probable fields of contact among the farmers along the lines of Häggerstrand's (1968) mean information field (MIF).

4.6 CONCLUSION

Low levels of adoption of CA were noted at Shewula attributed to various reasons including lack of awareness and basic knowledge about the system. The lack of information poses a challenge to the country to encourage research and other of information generation to address the information gap on local scenarios noted above. Age and gender patterns were noted in the adoption of CA. Adoption of CA concentrated among farmers in the middle ages of between 30 years and 59 years with no adoption among farmers in the 20s and above 59 years. Female farmers adopted CA more than their male counterparts. However, this situation may be misleading as some of the female could be acting on delegated responsibility from husbands that may be away from home for various reasons during the survey. The fact that most of adopters had formal education demonstrates the role of formal education in the enlightenment of farmers. The observations made above imply the need for targeted training at Shewula. This implies the importance of implementation of awareness raising campaigns and training activities tailor-made for the youthful farmers and older farmers as well as for farmers lacking formal education.

The spatial distribution where farmers willing to adopt CA clustered around those practicing the system demonstrates possibilities of transfer of information among the farmers. The influence of farmers practicing conservation was mentioned in unequivocal terms in the focus groups. Hence it is recommended that farmers practicing the system be equipped with basic training skills and resources to facilitate transfer of knowledge and information about the system to neighbouring farmers. This must be pursued alongside intensification of awareness raising campaigns and training activities. These efforts would address the noted lack of awareness observed and stimulate adoption of CA. The fact that advantages of CA over conventional farming were highlighted as key factors in the adoption of the system calls for information about the benefits of the system to be disseminated to the farmers. This may help dispel some of the misconceptions about the system that discouraged farmers from adopting it. Research in the social, economic and scientific aspects of CA needs to be encouraged especially its ability to increase yields in a sustainable manner, reduce farming costs, control soil erosion and maintain fertility, retain soil moisture and organic, to name but a few.

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CHAPTER 5

THE INFLUENCE OF CONSERVATION AGRICULTURE ON MOISTURE AND ORGANIC MATTER CONTENT IN SOIL UNDER CULTIVATION AT SHEWULA IN SWAZILAND

5.1 BACKGROUND

About 70% of the farmers in Swaziland grow crops mainly for subsistence purposes and they predominantly practice conventional farming techniques under rain fed conditions (Forsyth-Thompson, 2010; FAO, 2013). The prevalent farming techniques involve soil tillage and removal of stubble from previous crops with an intention to create a "good" seed bed to facilitate, among other things rooting of the crops (Fowler, 1999). Persistent drought experienced since 1990, characterised by below normal and erratic rainfall has adversely affected rain fed agriculture and caused a significant decline of maize production from annual average of about 100,000 metric tonnes in the 1980s to approximately 70,000 metric tonnes after 2000 (Sergeant, 2003; Smith, 2003; Swaziland Vulnerability Assessment Committee, 2010; IRIN, 2012; FAO, 2013). On the other hand, domestic maize requirement increased from 90,000 metric tonnes in the 1980s to about 115,000 metric tonnes in 2011 (Swaziland Vulnerability Assessment Committee, 2010; IRIN, 2012). Maize, being a staple food, is a preferred crop by subsistence farmers and it accounts for 73% of the total cereal consumption in the country (Mamba, 2003). Other grains such as rice (23%) and wheat (4%) are imported and are consumed in steadily increasing amounts especially in the urban areas (Smith, 2003). Food security remains the biggest challenge experienced by the country as approximately 11% of the population is affected by food insecurity (WFP, 2013). The country is able to meet only about 60% of its domestic maize requirements the remainder is acquired through *ad hoc* and unsustainable means including imports (mainly from South Africa) and food aid (Riddell and Manyatsi, 2003; FAO, 2013).

The apparent failure of rain fed agriculture to yield adequately under the prevailing farming systems and the prolonged drought necessitated introduction of new farming techniques. Actually, adapting agriculture to a potentially drier future is necessary particularly in the era of climate change (Biello, 2011). Hence the Government of Swaziland introduced CA in 2000 and encouraged its adoption by subsistence farmers especially in the drought prone areas on the eastern part of the country. Conservation agriculture, as a farming system, was recommended in the National Action Plan (NAP) for the implementation of the Convention to Combat Desertification (CCD) (SEA, 2000). Moreover, a survey by Calegari (2000) also showed very critical conditions for small-scale rain fed agriculture at Shewula as a result of soil erosion, mono-cropping with maize and vulnerability to drought.

The introduction of CA was supported by the FAO through a project titled "Awareness Creation on Conservation Agriculture" (TCP/SWA/2909) that lasted from 2001to 2005. The project sought to encourage adoption and practice of CA techniques by subsistence farmers. During implementation of the project, several testing and validation units (TaVUs) were established in four pilot areas within the four Agro-climatic regions of Swaziland including Shewula, where two TaVUs were created. TaVUs were initially run by CA specialists who used them for experiment and demonstrations during training of the local farmers. The TaVUs were later handed over to trained local farmers to utilize and continue with the training of other farmers.

Conservation agriculture, as a farming system, is regarded as a bundle of farming techniques with inherent basic principles such as minimum or no tillage, maintenance of soil cover through retention of stubble as well as cropping patterns that include intercropping and crop rotation (Dumanski *et. al.,* 2006). Of significance is that CA maintains a permanent or semi-permanent organic soil cover mainly from either growing crops but commonly from dead mulch (crop residue). The adoption process must ideally concentrate on one or two techniques of the system intended to be the ultimate form and goal to be achieved in CA (FAO, 2004). In Swaziland there were attempts to encourage farmers to cultivate traditional crops as part of CA adoption and not as CA adoption itself (Chapter 3). However, there were very clear intentions to concentrate on zero tillage and retention of stubble (soil cover) from previous crops as techniques to be practised in the country characterizing adoption and practice of the system (FAO, 2000). The former is intended to, among other things; reduce soil tillage costs and soil's susceptibility to erosion. The latter was intended to, among other things, achieve soil cover mainly to conserve moisture and increase organic matter content in the soil as a response to the problems of persistent drought and loss of soil fertility respectively. Usually, the retention of 30% soil cover by crop residue characterizes the lower limit of classification for CA practice (Baker *et al*. 2002). For organic matter content it is mentioned that most soils contain between 1-6% and the content levels are an indication of the amount of plant residue retained in the soil (Geocities, 2009). The focus of the study on estimation of soil cover and amount of retention of crop residue and their influence on soil moisture and organic matter content. Other important CA techniques such as intercropping and crop rotation were already practiced the local subsistence farmers as established in Chapter 3 above.

It was of interest to the study to ascertain the extent to which the local farmers have managed to achieve adequate soil cover to proportions above the 30% minimum as well as significant accumulation of crop residue on the soil. Specifically, have the farmers achieved the ideal soil cover and accumulation of crop residue to be classified as practicing CA? Moreover, have soil cover and accumulation of crop residue made significant contribution to improvement and retention of water and organic matter content in the soil? This information is crucial for local farmers to improve their awareness and knowledge about the advantages of CA especially when compared with CF. It is estimated that only about 5% of the farmers adopted CA at Shewula between 2000 and 2010 (Chapter 4). One of the main reasons for the low adoption status of CA at Shewula is the lack of comprehensive understanding of the system among the local farmers especially facts concerning the system's ability to sustain crop production under the prevailing drought (SADCICART, 2009; ICARDA, 2012; Mlipha, 2014). Currently, local information on CA is lacking (Dlamini & Masuku, 2010). Therefore the study intended to generate information about CA based on the local context and circumstances as well as basic soil variables familiar and of major concern to local farmers. These variables are soil moisture and organic matter content.

Driving the study were assumptions that the farmers practicing CA at Shewula have achieved adequate soil cover exceeding 30% in their plots as well as a significant accumulation of crop residue above the range of 1 to 6% explained above. Further assumptions were that moisture and organic matter content would be significantly higher in soils under CA than in soils under CF. Thierfelder *et al.* (2009) noted that CA has a potential to increase moisture content in soils after they observed that on average soil moisture was higher throughout the seasons in CA plots than in CF plots. According to the results of the questionnaire survey the farmers apportion greater value to organic matter content in the soil hence; the most preferred soils are those with dark to black hue as they are perceived to have high humus content and thus fertile. The farmer's perception of soil fertility is not far from reality as humus is an important reserve for soil nutrients such as Nitrogen (N), Phosphorous (P), Potassium (K) and Sulphur (S) (Funderburg, 2001). Humus is a very stable form of organic matter that prevails in soils for long periods and together with water content are perhaps the two basic soil features of concern to local subsistence farmers especially in areas experiencing low rainfall amounts.

5.2 THE STUDY AREA AND SITES

5.2.1 Description of Shewula

Shewula is a rural settlement situated in the northern-eastern part of Swaziland on the Lubombo plateau at about 500 metres above sea level (Figure 5.1). It lies along longitude 32° 00' and 32°

east and Latitude 26° 03’ and 26° 09’ south. The area is relatively dry with a long term annual average rainfall of 700mm, which it has failed to reach for past 10 years due to persistent drought gripping the country. Day time temperatures are generally warmer in summer averaging about 27°c and cooler winter averaging about 10°c. The area is characterised by a rugged escarpment terrain and indigenous woodlands stretching along the Mbuluzi River. The soil is mainly loose with small rock pebbles and highly susceptible to erosion while is water retention capacity is poor owing to its loose texture (Figure 5.2). Shewula experiences persistent drought spells which have significance effects on the production of food crops such as maize yet 80% of the approximately 10 000 people of Shewula area depend on rain fed subsistence farming for their livelihood. The remainder is engaged in wage based employment in the neighbouring commercial sugar-cane plantations and private farms. Maize, being a staple food, is grown on a wide scale at Shewula and the yields, reflecting the national situation, are continuously declining due to the persistent drought, lack of tractors and animal traction, limited access to agricultural inputs and impacts of HIV/AIDS (Mlipha, 2005; Save the Children Fund, 2003; IRIN, 2012; WFP; 2013). There are a variety of other crops grown including traditional crops such as *jugo* beans, cassava, pearl millet to name a few, albeit on a small scale, which are yet to be documented. Moreover, Shewula is within the foot and mouth disease quarantine area which places constraints on selling of livestock in times of need. As a result the cattle herds are relatively small per homestead (Mlipha, 2004).

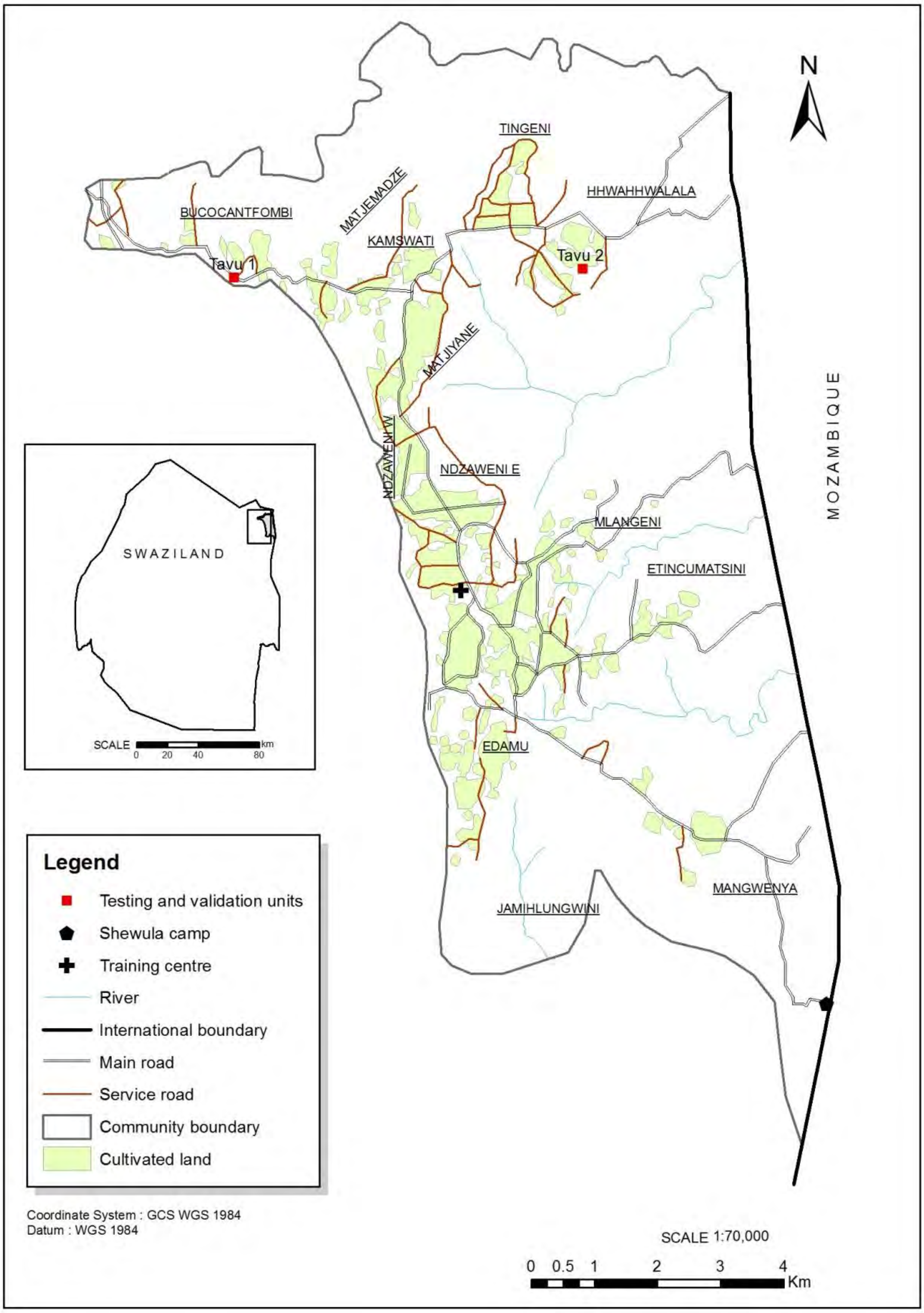

Figure 5.1 Map of Shewula showing the location of the two Testing and Validation Units (modified from Figure 3.1 above)

Figure 5.2 Soil in a cassava field at the Shewula chiefdom (Note the 10cm camera bag for scale)

5.2.2 Study sites

Sampling was conducted in the two TaVUs located at Bucocantfombi and Hhwahhwalala where there are plots under CA. Outside the TaVUs are cultivation plots under CF (Figure 5.1). The plots under CA were all fenced to prevent livestock encroachment while those under CF were not fenced and were therefore treated as control sites during the study.

The TaVU located at *Hhwahhwalala* was referred to as Testing and Validation Unit 1 (TaVU 1). Plots in the TaVU 1 had an east-west orientation on a gentle sloping terrain (about 2%). Both the CA and CF plots had a rectangular shape and were of similar average size of about 1, 660 m^2. The soil in both plots was sandy loam with dark-grey hue with high susceptibility to rapid water infiltration and soil nutrient leaching. The land was not under cultivation as it was winter and visible crop residue indicated that maize was cultivated as the main crop while cowpeas and *jugo* beans were secondary crops.

The TaVU located at *Bucocantfombi* was referred to as Testing and validation Unit 2 (TaVU 2). Plots in the TaVU 2 also had a rectangular shape and assumed a north-south orientation with a slope angle of about 4% and similar average size of about 1, 350 m^2. The soil in both plots was mainly dark to dark brown loam soil. The residue accumulated showed that the previous crops cultivated that year were maize as the main crop with cow peas as a cover crop.

5.3 METHODS

5.3.1 Sampling

The study was conducted in winter of 2013. This is the driest season in Swaziland and culturally livestock graze on crop residue on unfenced cultivation plots. Data were collected in the two TaVUs described above. In the TaVU 1 **s**ampling was conducted on 10 sampling points derived from 15% of 5m x 5m grid from the size of the two plots stated above. In the TaVU 2 sampling was conducted on 8 sampling points derived from 15% of 5m x 5m grid from the area of the size of the two plots stated above.

Systematic random sampling was used to select the sampling points on the four sites based on 5m x 5m grid. The grid squares being located at regular intervals in linear pattern were ideal for the systematic sampling method. Soil samples were collected from the centre of each square which were selected at intervals of 15 metres. To overcome some of the shortcomings of the sampling method noted by Dixon & Leach (1977) the first sampling point in each row was selected using a table of random numbers. A 1m x 1m quadrat was marked at the centre of the each selected sampling point to mark confines of field measurements. Twenty five sampling points are normally ideal in a soil survey but Rowell (1994) mentions that sampling points less than 25 are also acceptable especially in small plots like the ones at Shewula. In all 20 and 16 sampling points were selected in the TaVUs 1 and 2 respectively in both the CA and CF plots.

Soil samples were collected in the mid-points of the 1m x 1m quadrats marked at the centre of the grid at the depths of 15cm, 30cm and 45cm. It was assumed that the mentioned depths are within the effective rooting zone of most of the crops cultivated at Shewula. Some studies however sampled as far deep as 80 cm especially when using the Anderson and Ingram's (1993) procedure. Soil samples were collected in June (2013). Being the winter season in Swaziland there was no rainfall recorded in the previous month and the soils were very dry. While this was ideal to establish soil with higher water retention capacity between the two farming systems but the dryness made it difficult to collect soil samples below 40cm using the ordinary soil augur.

5.3.2 Assessment of soil cover

Assessment of soil cover and accumulation of crop residue (litter) was confined to the area within the 1m x 1cm quadrat. The percentage soil cover was estimated to the nearest 5% having divided the quadrat into four equal parts (quarters) and further subdivisions of the quarters. The average of all percentage soil cover (Y) values of the sampling areas (10 and 8 respectively) gave the estimated percentage soil cover of a plot.

$$Y = \frac{\sum x}{n}$$

Y average % soil
∑x sum of % soil cover in each quadrat (sampling point)
n number of quadrats (sampling points)

5.3.3 Assessment of accumulation of crop residue

To establish the amount of accumulated crop residue or litter in the quadrat; litter within the quadrat was collected and weighed in the field. After weighing, the residue was returned to the soil and spread over the quadrat. The average weight (g/m^2) of all the sample points (Z) gave an estimated weight of crop residue per metre square for the plot.

$$Z = \frac{\sum x}{n}$$

Z average mass of litter (g/m^2)
∑x sum of mass of litter in each quadrat (sampling point)
n number of quadrats (sampling points)

5.3.4 Soil moisture content

The ***Gravimetric method*** (Foster, 1998; Brady and Weil, 1999; Evert, 2008) was used to determine the moisture content in the soil samples. This is a mass based moisture content analysis and is ideal for comparison purposes and useful to detect changes in soil volumes on different tillage patterns (Hignett and Evertt, 1986; Evertt, 2008). Dane and Topp (2002) view this method as standard and reliable though may not be ideal where high accuracy is required. The standard procedure of sample preparation (according to American Society for Testing and Materials - ASTM) was applied and samples were placed for 24 hours in an oven to dry at a temperature of 105^{o}C. The moisture content (**u**) in the soil samples was initially expressed by mass; mass of fresh soil samples (M_{wet}) minus mass of soil samples after drying (M_{dry}). Thereafter for purposes of this study the soil moisture was expressed as percentage (%) of soil samples' dry weight:

$$\mathbf{u} = \frac{M_{wet} - M_{dry}}{M_{dry}} \times 100$$

u % moisture content in the sample
$\mathbf{M_{wet}}$ mass of the fresh soil sample
$\mathbf{M_{dry}}$ mass of the dried sample

5.3.5 Determination of organic matter content

The ***ignition*** method (Reddy, 2002) was used to determine organic matter content in the soil samples. This test is performed to determine organic matter content as a ratio (percentage) of mass of organic (carbon) in a given soil to the mass of the dry soil solids. This is a standard method for measurement of soil organic matter content and suitable for resource poor institutions because very few and simple equipment is required (small furnace/oven, balance, porcelain dish, spatula and tongs. The standard treatment followed involved the drying of the samples to remove moisture. The samples were put in the oven at 440^{o}c for 24 hours to remove carbon in the soil (assumed to be the only volatile substance in the soil after water has been removed during drying of the samples). Below is the procedure that was followed:

- Determination of the mass of the dry samples (M_D)

$$M_D = M_{PDS} - M_P$$

M_{PDS} mass of petri dish and soil sample
M_P mass of empty, clean and dry petri dish

- Determination of the mass of the burnt soil (M_A)

$$M_A = M_{PA} - M_P$$

M_{PA} mass of petri dish and burned soil
M_P mass of petri dish

- Determination of the mass of organic matter (M_O)

$$M_O = M_D - M_A$$

- Determination of the organic matter content in the samples (OM)

$$OM = \frac{M_O}{M_D} x\ 100$$

5.3.6 Verification of test results

The soil moisture and organic matter content results recorded for presentation were acquired after three trials per sample treated.

5.3.7 Data analysis

The analysis was conducted using SPSS v.20. The Spearman Rank Correlation Co-efficient was used to establish relationships between soil cover and organic matter accumulation as well as relationships between soil cover and moisture and organic matter content. In the interpretation $r < 0.50$ was regarded as weak correlation and $r > 0.5$ was regarded as strong correlation at significance of *0.01* and degree of freedom of n+n-2 that is *18* for the CA plot and *14* for the CF plot. The Student *t*-test was used to ascertain the extent of difference between soil moisture and organic matter content in the CA and CF plots. The test was conducted at probability value (*Sig.* value) of *0.05* and degrees of freedom of 18 (TaVU1 plots) and 14 (TaVU 2 plots). If probability values were greater than (>) *0.05* it meant no significant difference in the soil moisture or organic matter values in the CA and CF plots (Appendix E). If probability values were less than (<) *0.05* there was statistically significant difference between soil moisture or organic matter content in the CA and CF plots. The study used the Levene's test at *0.05* probability level (*Sig*. value) to determine statistical significance of the *t*-test results (Appendix E). A probability value of less than (<) *0.05* meant the variances were significantly different and the *t*–test results were invalid and difficult to make conclusive inferences from them. A probability value that was greater than (>) *0.05* implied that the variances were not significantly different and hence greater confidence in the validity of the *t*-test results.

5.4 RESULTS

5.4.1 Testing and validation Unit 1 (DLA-TVU)

5.4.1.1 Amount of Soil Cover

The study was conducted in winter when livestock graze on crop residue in unfenced cultivation plots commonly under CF. Therefore the control plots under conventional farming were without any soil cover (bare).

Estimation of soil cover per sampling point (quadrat) in the CA plot in TaVU 1 shows that it ranged from 25% to as high as 90% (Figure 5.3). The average percentage coverage was 61.5% and it was significantly above 30% (which denotes lower limits of classification of CA). The average percentage of soil cover therefore indicates success in the retention of adequate soil cover signalling achievement of this fundamental aspect of CA. Patches of bear soil however were visible especially in sampling point 2 where the coverage was as low as 25% yet in sampling point 8 there was almost complete soil cover at 90%.

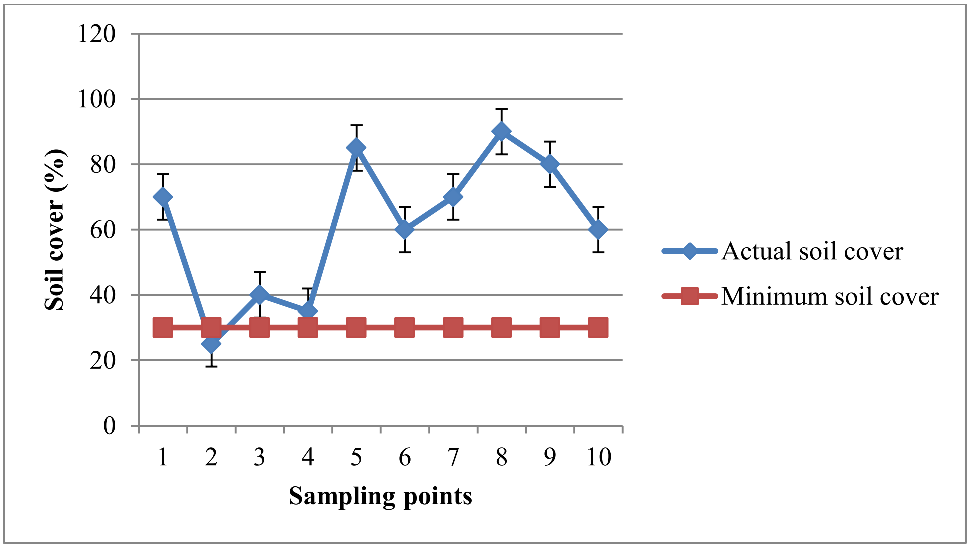

Figure 5.3 Percentage soil cover in the Testing and Validation Unit 1

5.4.1.2 Accumulation of crop residue

Correlation was significant (*Pearson r = 0.96, $p < 0.01$*) between soil cover and amount (mass) of crop residue that has accumulated. Accumulation of crop residue in the plot ranged from 55g/m^2 to 400g/m^2 (Figure 5.4). However, it is difficult to state the significance of the noted accumulation mass since it was difficult to establish a critical mass for accumulation of crop residue on CA. The fact that in sampling points 5 and 8 the accumulation reached 400g/m^2 indicate a failure for the farmers to build significant mass of crop residue in the other eight sampling points where the mass was 200g/m^2 and below (Figure 5.3).

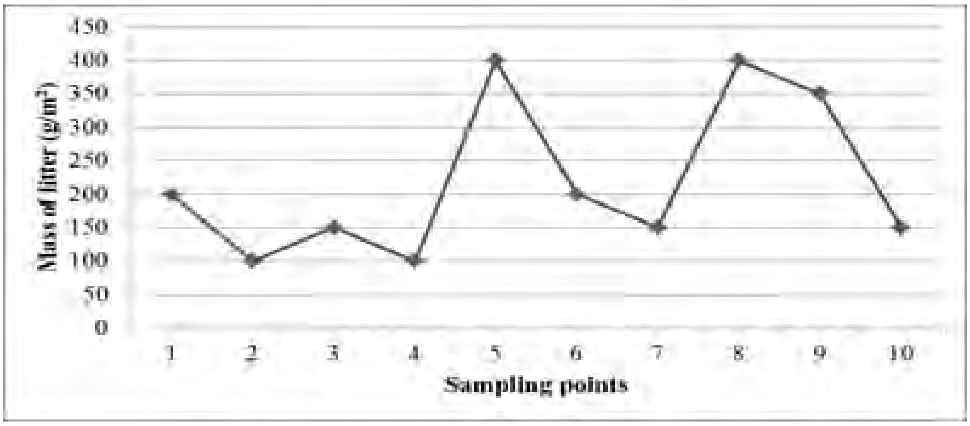

Figure 5.4 Mass of litter in the Testing and Validation Unit 1

5.4.1.3 Soil moisture content

Soil moisture content at 15cm depth in the CA plot ranged from 1.6 % in sampling point 3 to about 7.1% in sampling point 5. Sampling point 5 also had the highest mass of residue. Soil moisture content in soil in in the CF plots was below 4.0% in all the sampling points (Figure 5.5). The mean percentage moisture content at 15cm depth of the CA plot was 3.54% slightly higher than that of the CF plot which was 2.97% demonstrating no significant difference between soil moisture content in the two farming systems (*$p > 0.05$*).

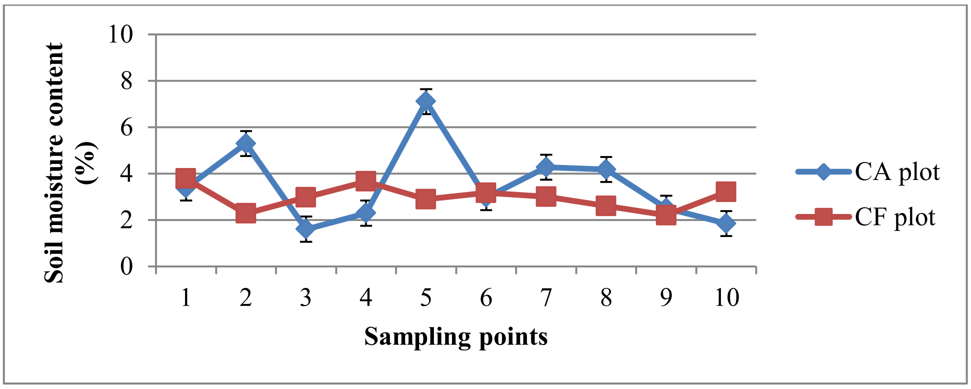

Figure 5.5 Soil moisture content at 15cm depth in conservation agriculture and conventional farming plots

Soil moisture content at 30cm depth was consistently high in all sampling points in the CA plot except in sampling point 4 which had one of the lowest values in percentage soil cover and mass of residue. The percentage moisture content in the CA plot ranged from 5.67% to 12.89% while in the CF plot it ranged from 4.99% to 7.92% (Figure 5.6). The mean percentage moisture content at 30cm depth of the CA plot was 9.21% and was higher than that of the CF plot which is 5.93% and the difference between the two plots was significance (Student *t test, $p < 0.05$).* This indicated that soil cover and accumulation of crop residue associated with CA had an influence in soil moisture content.

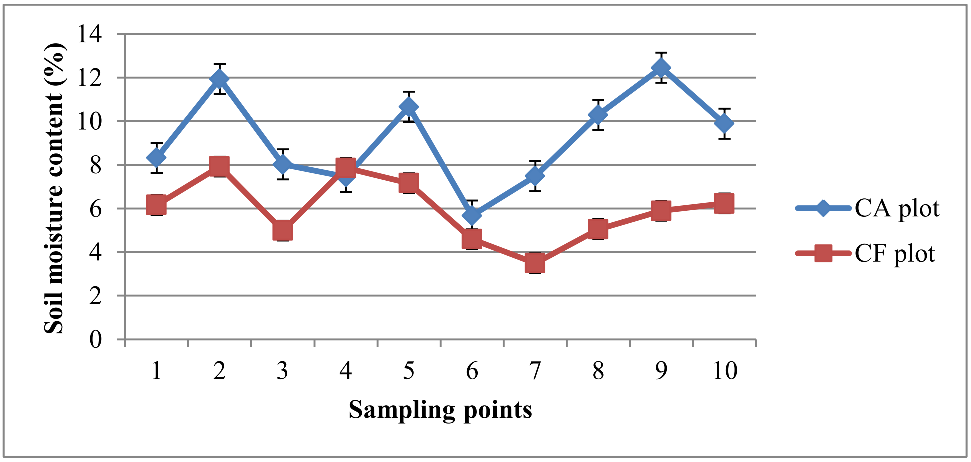

Figure 5.6 Soil moisture content at 30cm depth in conservation agriculture and conventional farming plots

Soil moisture content at 45cm depth was consistently higher in all sampling points in the CA plot than in the CF plot. The percentage moisture content in the CA plot ranged from 5.29% in sampling point 4 to 14.73% in sampling plot 5. In the CF plot it ranged from 3.64% in sampling point 7 to 7.45% in sampling plot 4 (Figure 5.7). The mean percentage moisture content at 45cm depth of the CA plot was 10.06% and was higher than that of the CF plot which was 5.88%. There was a significant difference between soil moisture content in CA and CF plots (*students t test, $p < 0.05$*).

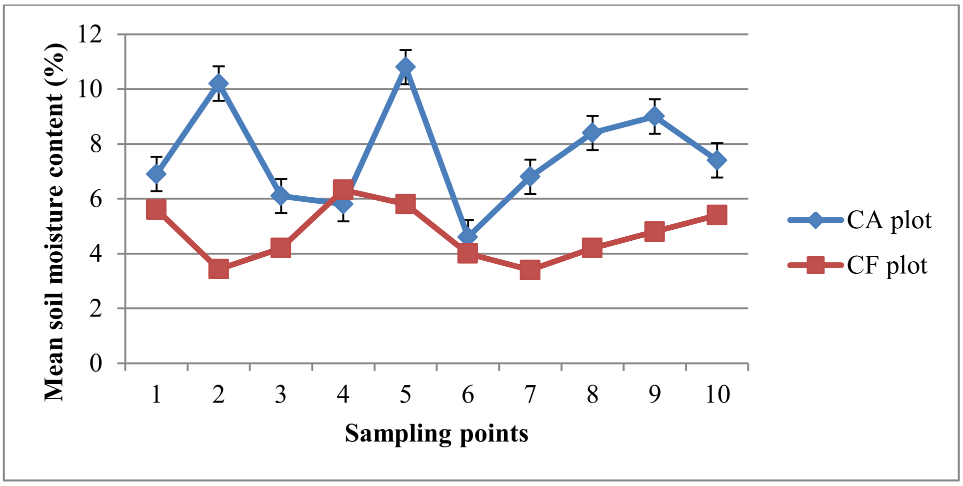

Figure 5.7 Soil moisture content at 45cm depth in conservation agriculture and conventional farming plots

Average soil moisture content according to depth was lower at 15 cm in both CA and CF plots and progressively increased with depth at 30 cm. In the CA plot moisture continued to increase and was highest at 45 cm. In the CF plot moisture content decreased towards 45 cm and remained highest at 30cm (Figure 5.8). The average soil moisture content for the CA plot was significantly higher at 8.2% ($p < 0.05$) than that of the CF plot which was 4.7%. This could be attributed to the influence of soil cover and accumulated crop residue. Actually the correlation between average soil moisture in the two farming system was significant (*Spearman* $r = 0.718$, $p < 0.01$). The influence of accumulated crop was also significant in the retention of moisture by the soil under CA (*Spearman* $r = 0.698$, $p < 0.01$).

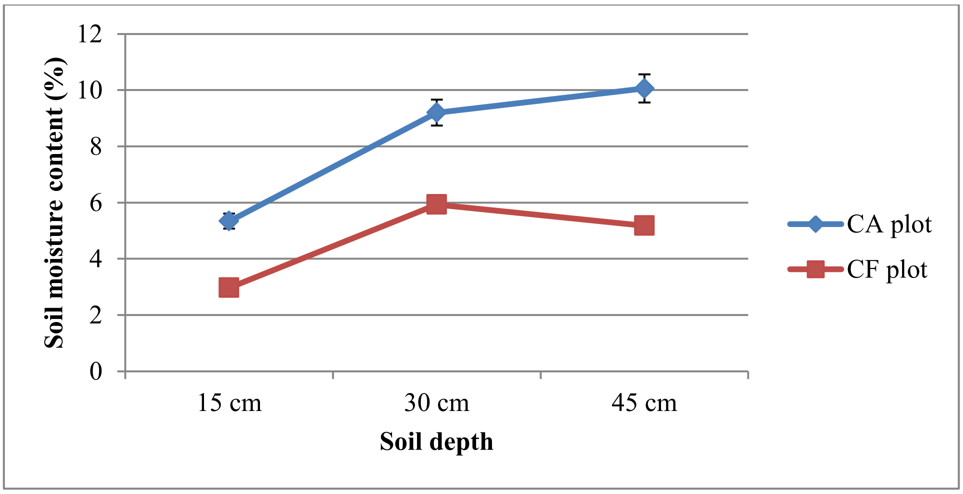

Figure 5.8 Average soil moisture content in soils under conservation agriculture and conventional farming plots

5.4.1.4 Organic matter content

At 15 cm the organic matter content was generally higher in the CA plot than in the CF plot in all the sampling points except 5 and 10. Organic matter content in the CA plot ranged from 4.7% to 9.88 while in the CF plot ranged from 4.6% to 8.43% (Figure 5.9). There was less variability in the organic matter values in the two farming systems (*Lavene's test = 0.093, p>0.05*). The mean organic matter content in the CA and CF plots was 7.18% and 6.16% respectively. Though the mean organic matter content in the CA plot was higher than in the CF plot the difference between the two was not significant (*p > 0.05*). The noted difference of organic matter content in soils in the CA and CF plots may be attributed to other factors but not soil cover which differentiates the systems of farming.

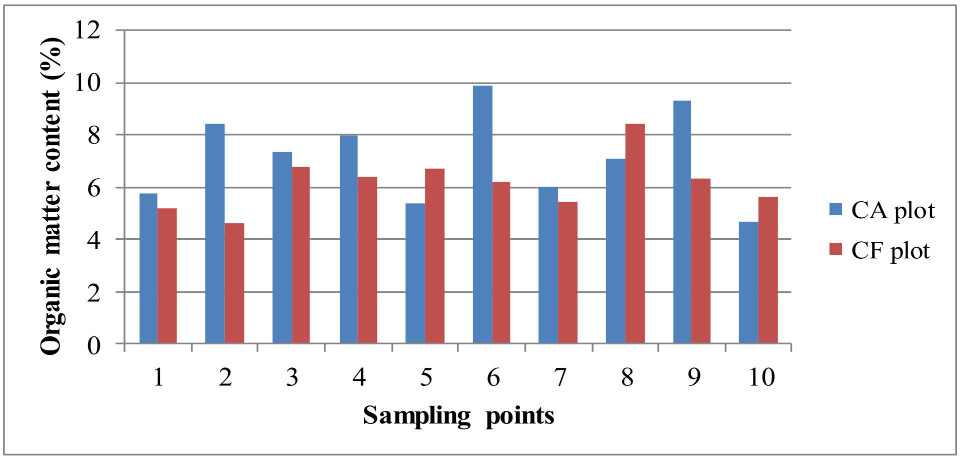

Figure 5.9 Organic matter content at 15cm in conservation agriculture and conventional farming plots

At 30 cm the organic matter content in the CA plot ranged from 3.68% to 11.63% and was only significantly higher in sampling points 2 and 6 whereas in the other points it was either slightly higher or lower than in soil under CF (Figure 5.10). In the CF plot, the organic matter content ranged from 2.72% to 8.43%. The Lavene's test indicates that there was no significant variability (*Lavene's test = 0.93, p>0.05*) in the values for organic matter content in the CA and CF plots. The mean organic matter content in the CA and CF plots were 6.98% and 5.92% respectively. Though the mean organic matter content in the CA plot appeared higher than in the CF plot the difference between the two was not significant (*p > 0.05*). The noted difference may be attributed to others factors but not soil cover that differentiate the CA plots from the CF plot.

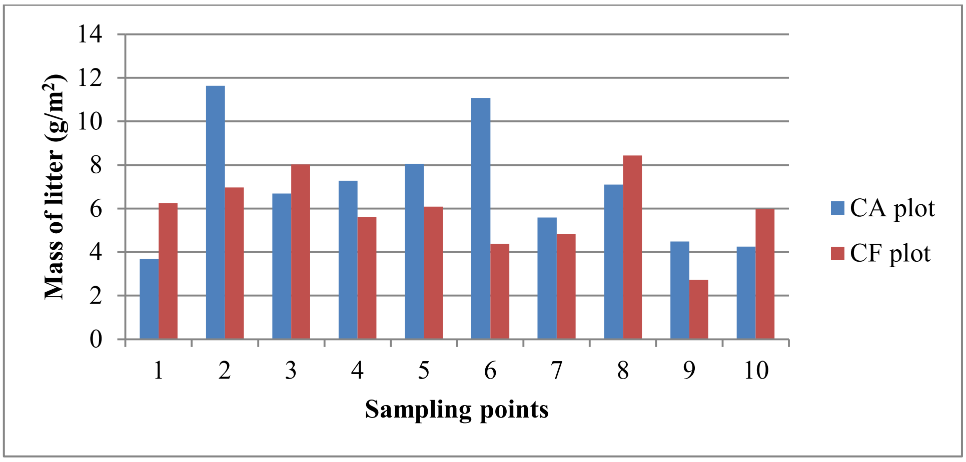

Figure 5.10 Organic matter content at 30cm in conservation agriculture and conventional farming plots

At 45 cm the organic matter content in the CA plot ranged from 3.77% to 12.96% and was significantly higher in sampling points 2 and 6 whereas in the other points either slightly higher or even lower than in soil under CF (Figure 5.11). In the CF plot, the organic matter content ranged from 3.50% to 8.26%. The Lavene's test indicates that there was no significant variability (*Lavene's test = 0.078*, $p > 0.05$) in the CA and CF figures for organic matter content. The mean organic matter content in the CA and CF plots were 7.69% and 5.39% respectively. Though the mean organic matter content in the CA plot appeared to be higher than in the CF plot the difference between the two was not significant ($p > 0.05$).

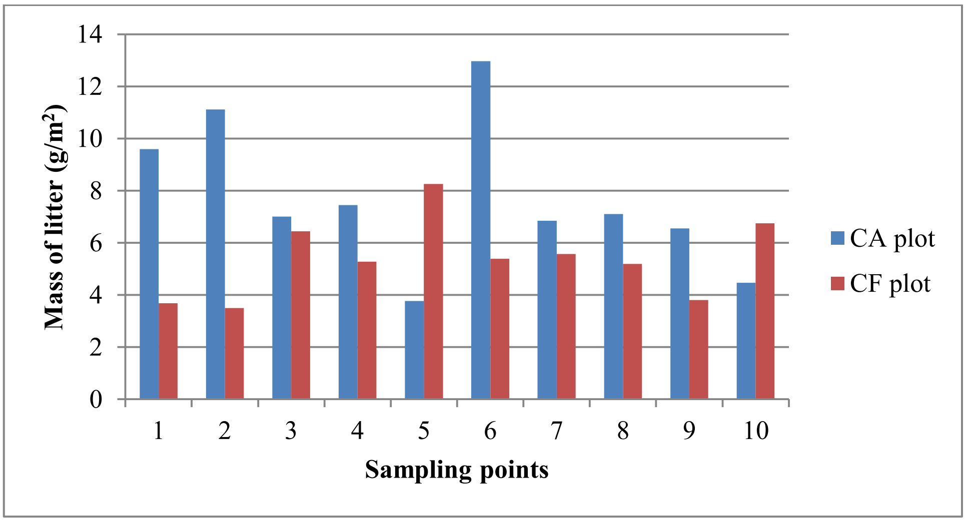

Figure 5.11 Organic matter content at 45cm depth in conservation agriculture and conventional farming plots

Average organic matter content according to depth indicates higher content in soils in the CA plot in all the depths. In the CA plot organic matter content was relatively higher at 15cm (7.18%) and 45cm (7.68%) and was relatively lower at 30cm (6.98%). In the CF plot it was relatively higher in 15cm and declined progressively with increase in depth such that it was lowest at 45cm. The average organic matter content in CA plots was 7.82% while in the CF plot it was 5.82% (Figure 5.12). Greater variability was detected in the organic matter content values in both farming systems (*Lavene's test = 0.024, $p < 0.05$*). The average organic matter content in the CA plot though appeared higher but it was not significantly different from that of the CF plot ($p > 0.05$). Moreover, there was also a less significant correlation between soil cover and accumulated crop residue on organic matter content in the soil under CA (*Spearman $r = {}^{-}0.340$ and ${}^{-}0.312$* respectively, $p > 0.01$). The noted differences, therefore, may be attributed to others factors but not the influence of soil cover and accumulated crop residue which are elements that differentiate the CA plot from the CF plot.

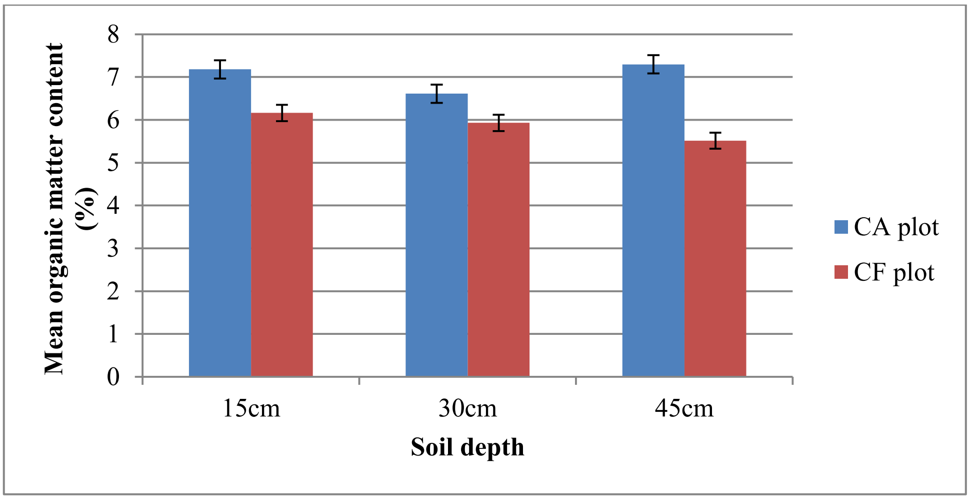

Figure 5.12 Average organic matter content in conservation agriculture and conventional farming plots

5.4.2 Testing and Validation Unit 2

5.4.2.1 Amount of Soil Cover

Estimation of soil cover per sampling point (quadrat) in the CA plot in TaVU 2 shows that it ranged from 5% to a maximum of 45% (Figure 5.13). The average percentage coverage was 22.5% and it was significantly below 30% (which denotes lower limits of classification of CA). The average soil cover therefore indicates failure in the retention of adequate soil cover signalling difficulty in the achievement of this fundamental aspect of CA. During fieldwork the CA plot was characterised by large patches of bare soil in all the 8 quadrats that were studied. There was also evidence of livestock intrusion into the CA plot hence the low percentage soil cover.

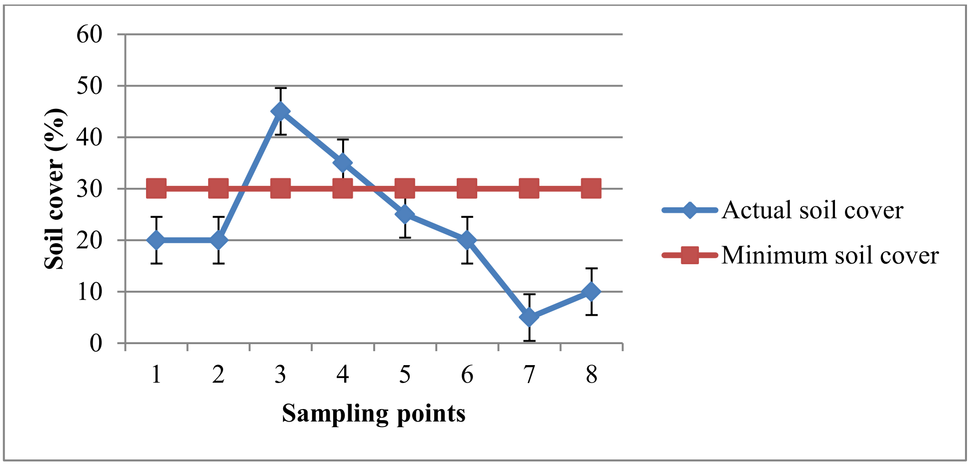

Figure 5.13 Percentage soil cover in the Testing and Validation Unit 2

5.4.2.2 Accumulation of crop residue

Correlation was significant (*Pearson* $r = 0.919$, $p < 0.01$) between soil cover and amount (mass) of crop residue that has accumulated in the CA plot. Accumulation of crop residue in the plot ranged from 55g/m^2 to 400g/m^2 (Figure 5.14). However, it is difficult to state the significance of the noted accumulation mass since it was difficult to establish a critical mass for accumulation of crop residue on CA. The fact that in sampling points 5 and 8 the accumulation reached 400g/m^2 indicates failure by the farmer to build significant mass of crop residue in the other eight sampling points where the mass was 200g/m^2 and below. There was evidence of livestock grazing inside the fenced CA plot attributed to lack of maintenance of the fence.

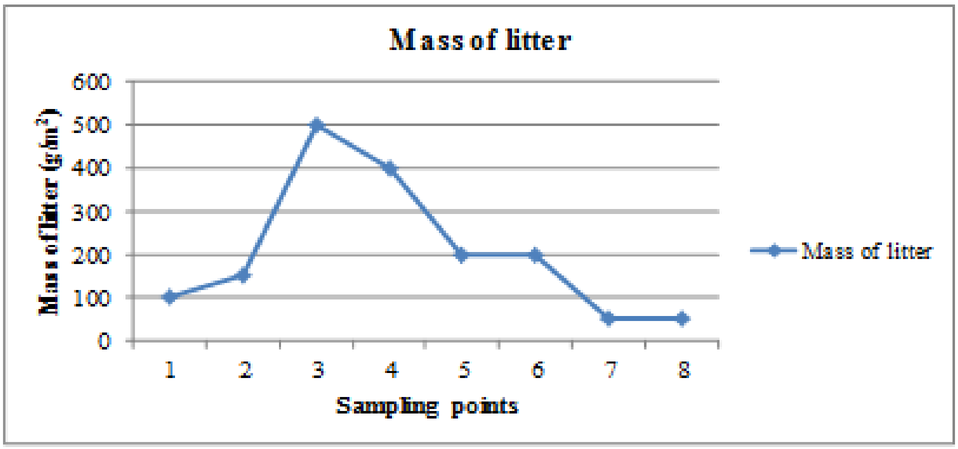

Figure 5.14 Mass of litter in the Testing and Validation Unit 2

5.4.2.3 Soil moisture content

Soil moisture content at 15cm depth was generally higher in all sampling points in the CA plot than in the CF plot. The percentage moisture content in the CA plot ranged from 9.3% in sampling point 5 to 18.05% in sampling point 4. In the CF plot it ranged from 8.10% in sampling point 4 to 11.05% in sampling point 3 (Figure 5.15). The mean percentage moisture content at 15cm depth of the CA plot was 12.10% and was higher than that of the CF plot which is 9.30%. The moisture content levels in the CA and CF plots demonstrated variability in the values (*Lavene's test 0.014, $p < 0.05$*). However, there was no significant difference between the two moisture content levels (*student's t- test, $p > 0.05$*).

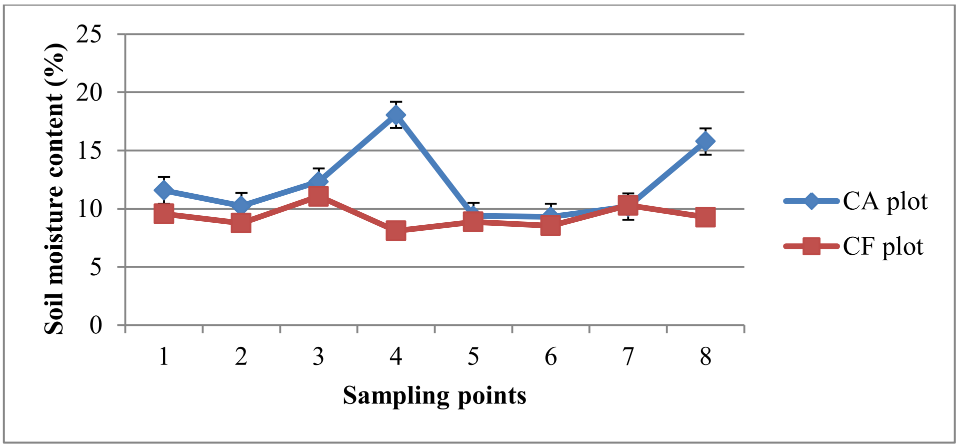

Figure 5.15 Soil moisture content at 15cm depth in conservation agriculture and conventional farming plots

Soil moisture content at 30 cm depth was marginally higher in some sampling points in the CA plot than in the CF plot. The percentage moisture content in the CA plot ranged from 9.99% in sampling point 5 to 20.00% in sampling point 4. In the CF plot it ranged from 9.46% in sampling point 1 to 14.88% in sampling point 6 (Figure 5.16). The mean percentage moisture content at 30cm depth of the CA plot was 13.90% and was higher than that of the CF plot which is 12.33%. The moisture content values in the CA and CF plots were variable (*Lavene's test 0.009, $p < 0.05$*). However, there was no significant difference between the soil moisture content levels in the CA and CF plots (*student's t- test, $p > 0.05$*).

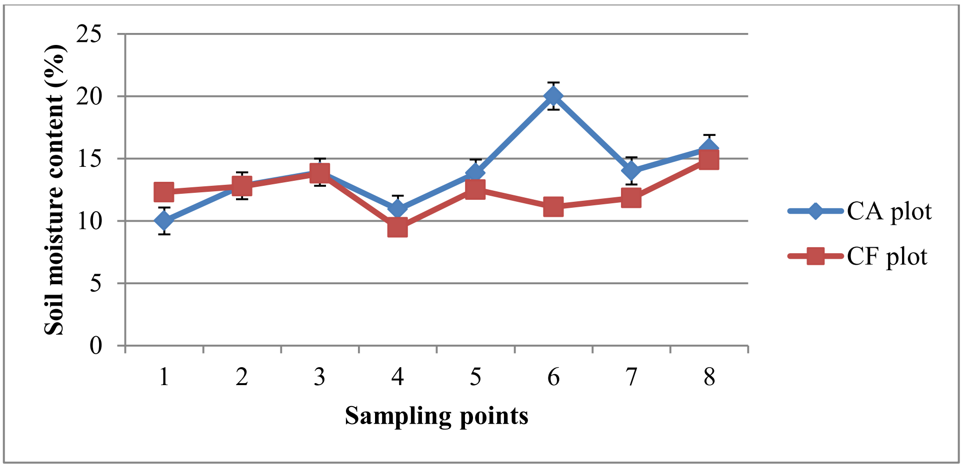

Figure 5.16 Soil moisture content at 30cm depth in conservation agriculture and conventional farming plots

Soil moisture content values at 45 cm depth in both the CA and CF plots approached being the same (*Lavene's test = 0.950, p > 0.05*). The percentage moisture content in the CA plot ranged from 12.81% in sampling point 2 to 20.73% in sampling point 6. In the CF plot it ranged from 11.44% in sampling point 4 to 16.02% in sampling point 8 (Figure 5.17). The mean percentage moisture content at 45cm depth of the CA plot was 15.69% and was higher than that of the CF plot which was 14.04%. There was no significant difference between the moisture content levels in the CA and CF plots ($p > 0.05$).

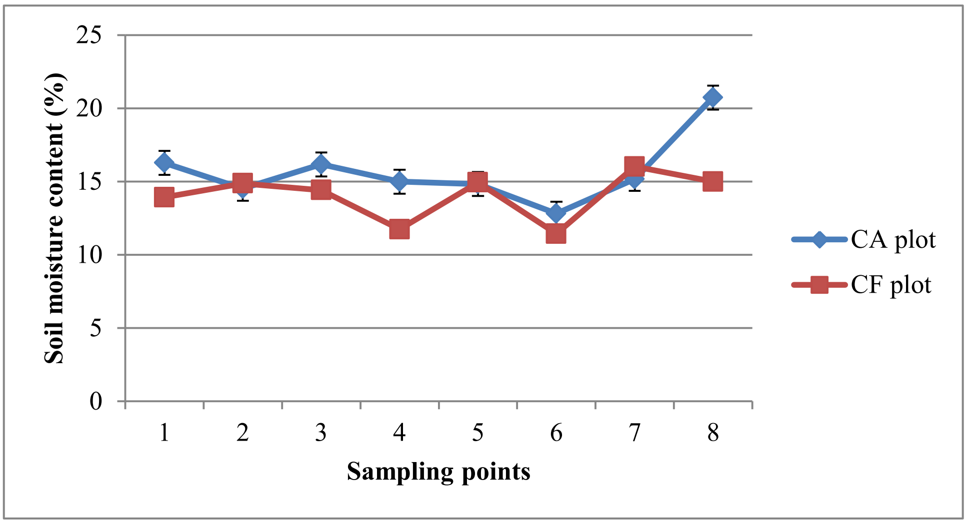

Figure 5.17 Soil moisture content at 45cm depth in conservation agriculture and conventional farming plots

Mean soil moisture content according to depth was lower at 15 cm in both CA and CF plots and increased progressively with depth (Figure 5.18). Soil moisture in the CA plot was slightly above that in the CF plot though the difference was not significant ($p < 0.05$). This implies that soils in the CA plot retained almost the similar amount moisture to that of the CF plot during the winter. The noted slight difference may be due to other factors or chance than the tillage systems and retention of soil cover which differentiate the farming systems on the two plots. An important observation was the higher soil moisture at 45cm than closer to the surface which favours deep rooted crops like sorghum.

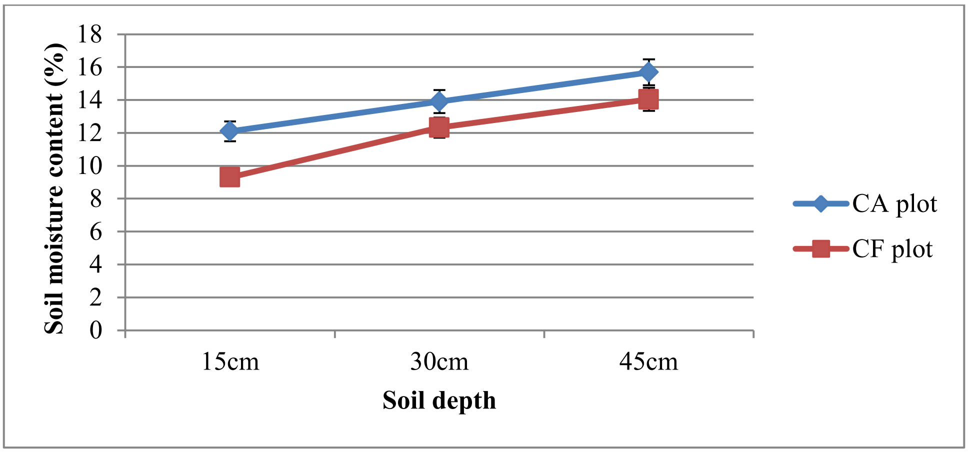

Figure 5.18 Average moisture content in conservation agriculture and conventional farming plots

5.4.2.4 Organic matter content

At 15 cm the organic matter content in the CA plot ranged from 4.39% to 12.66% in the CF plot it ranged 6.89% to 12.12% (Figure 5.19). Variability in the values of organic matter content in both plots was significant (*Lavene's test = 0.017,* $p<0.05$). However, average organic matter content at 15cm in the CA plot and CF plot was 8.89% and 8.73% respectively which implied no significant difference ($p > 0.05$). The noted difference may be attributed to others factors but not the systems of farming.

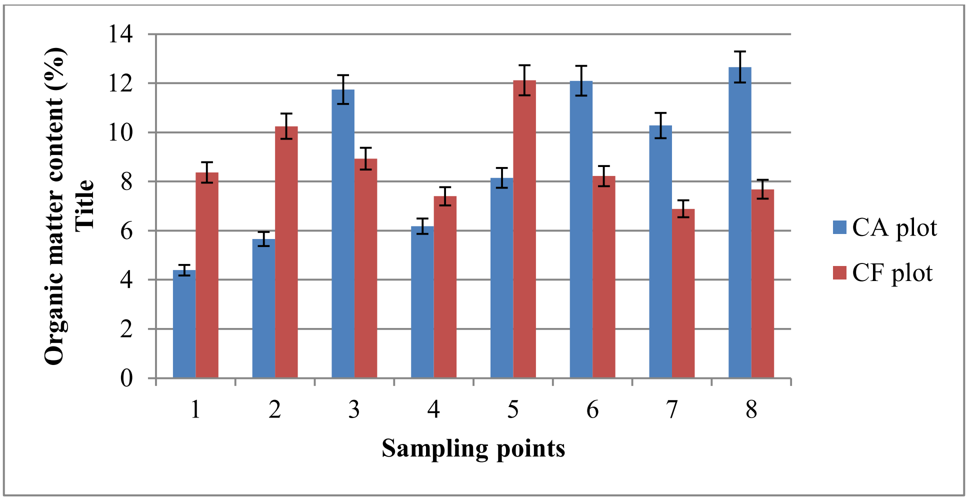

Figure 5.19 Organic matter content at 15cm depth in CA and CF plots

At 30 cm the organic matter content in the CA plot ranged from 4.50% to 12.00% in the CF plot it ranged 3.08% to 11.61% (Figure 5.20). Variability in the values of organic matter content in both plots was not significant (*Lavene's test = 0.413,* $p > 0.05$). Moreover, average organic matter content at 30cm in the CA plot and CF plot was 8.63% and 8.43% respectively which implied no significant difference ($p > 0.05$). The noted slight difference may be attributed to chance but not the soil cover which was the major difference between the farming systems.

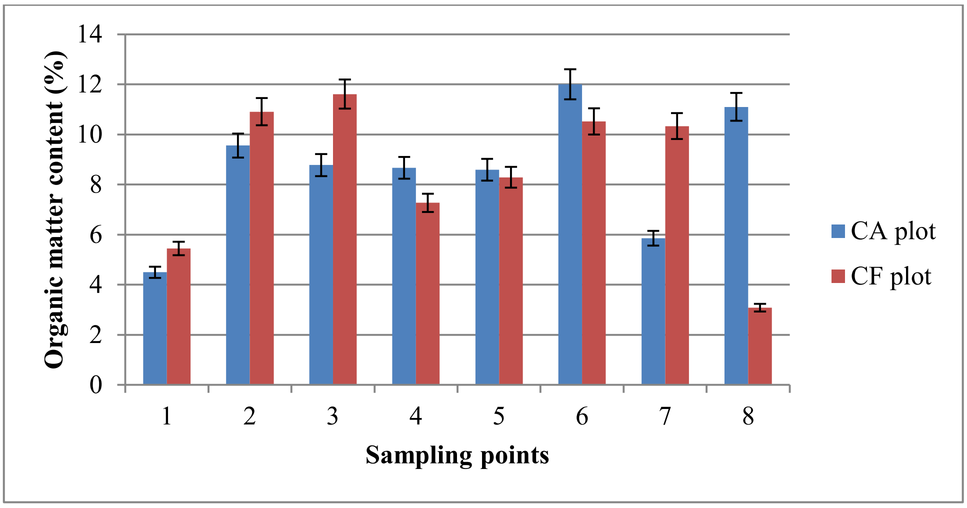

Figure 5.20 Organic matter content at 30cm depth in conservation agriculture and conventional farming plots

At 45 cm the organic matter content in the CA plot ranged from 3.48% to 10.78% in the CF plot it ranged 2.82% to 10.98% (Figure 5.21). Variability in the values of organic matter content in both plots was not significant (*Lavene's test = 0.892, p > 0.05*). Moreover, average organic matter content at 30cm in the CA plot and CF plot was 8.29% and 8.24% respectively which implied no significant difference (*p > 0.05*). The noted slight difference may be attributed to chance but not the soil cover which was the major difference between the farming systems.

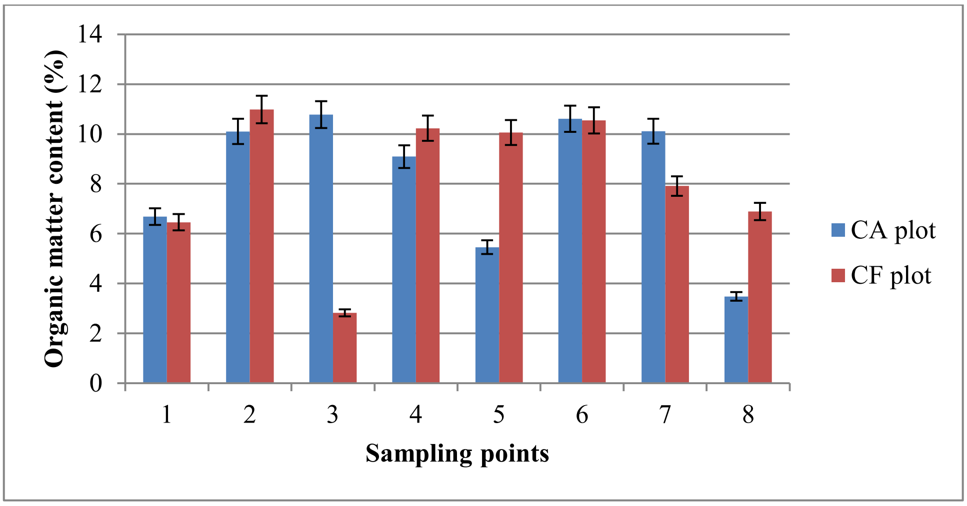

Figure 5.21 Organic matter content at 45cm depth in conservation agriculture and conventional farming plots

The average organic matter content in the CA and CF plots at the various depths was consistently higher in the CA plot (Figure 5.22). Average organic matter content in both plots was higher at 15cm (8.89% and 8.73% respectively) and progressively declined and reached the lowest at 45cm where it was 8.29% and 8.23% respectively (Figure 5.20). The overall average organic matter content in the CA plot was about 8.60% and in the CF plot it was estimated at about 8.40%. Based on the mean values given above there was no significant difference ($p > 0.05$) between organic matter content in soils in the CA and CF plots.

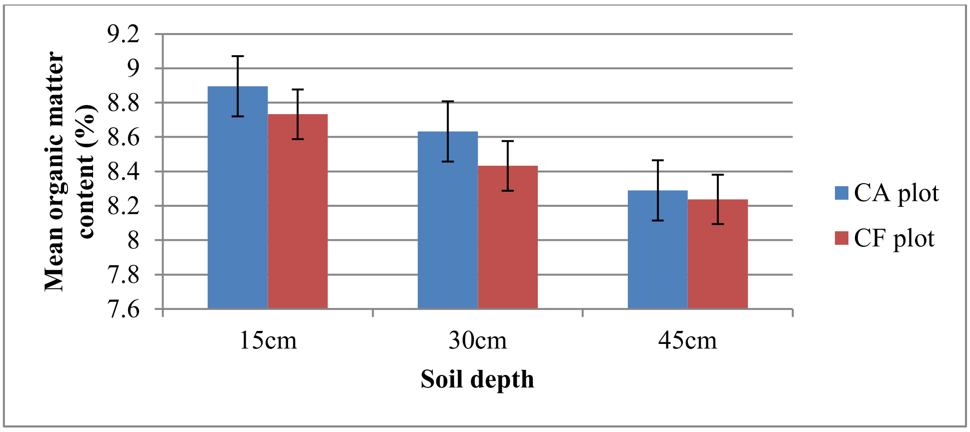

Figure 5.22 Average organic matter content in conservation agriculture and conventional farming plots

5.5 DISCUSSION

The study focused on soil cover and accumulation of crop residue (litter) they constitute the fundamental differences between CA and conventional farming as practiced by subsistence farmers in Swaziland. Moreover, soil cover and accumulation of crop residue contribute to increased soil moisture and organic matter content (Kemper and Derpsch, 1981). This happens in a number of ways but commonly soil cover and accumulated crop residue reduce rain water run-off and encourages infiltration (Frubam et al. 1985. At the same time they contribute to the build-up of soil organic matter commonly known as humus.

5.5.1 Testing and Validation Unit 1

A significant amount of soil cover was achieved in the CA plot to an average percentage of about 60%. This aspect of CA was achieved as it exceeds the 30% threshold commonly associated with lower limit of classification of CA (Baker *et al*. 2002). The soil cover achieved was attributed to the fencing of the CA plot which prevented livestock from grazing on the crop remains as it is the normal practice during winter. However, a potential to achieve more soil cover was noted based on the percentage of soil cover in sampling points 5 and 8 which was about 90%. This challenges the farmers practicing CA to consider means of increasing soil cover in the entire CA plots. To meet this challenge the farmers may consider cultivating leafy cover crops that may grow even in the dry season.

The accumulation of crop residue proved difficult to explain in the absence of a reference critical mass of achievement under conservation farming. Accumulation levels of up to 400g/m2 were observed in sampling point 5 and 8 which corresponded with amount of soil cover in the two points. The fact that 7 of the sampling points recorded 200g/m2 or below pointed to a potential for the farmer to achieve higher accumulation rates. Higher soil cover and crop residue accumulation may improve soil moisture and organic matter content.

Soil moisture content was statistically higher (significant at the 95% level) in the CA plot than in the CF plot in all the soil depths sampled. Thierfelder (2009) arrived at the same conclusion in his study of impact of CA on infiltration and soil moisture content in Zambia and Zimbabwe. He concluded that on average soil moisture content was higher throughout the seasons on CA plots than on CF plots and noted a potential for CA to increase crop productivity and reduction of crop failure due to drought. While in the CF plot soil moisture content declined at 45cm, under the CA plot soil moisture increased with distance and was higher at 45cm. This augurs well with maize and some legumes (common crops cultivated at Shewula) with most water uptake in depths lower than 60cm (Northwest Bean Growers Association, 2007). Actually less than 10% of water uptake by these crops takes place in depths below 60cm (NDSU, 1997). The influence of soil cover on soil moisture content was found to be significant (*Spearman* $r = 0.718$, $p < 0.01$). The influence of soil cover appeared true in sampling points 5 and 8 but the relatively higher soil moisture status in sampling point 2 with the lowest soil cover needed further explanation. Sampling point 2 was unique with higher organic matter content but not derived from crop residue as that was also lower compared to the other points. Probably the situation is sampling point 2 demonstrates the influence of pedological, climatic historical trends in land use as well as soil management practices which control organic matter content in soils (Smaling, *et. al,* 1997; Singh *et. al.,* 2011).

Organic matter content was relatively higher in the CA plot than in the CF plot at all the soil depths sampled. However, the difference between the two plots was not significant ($p > 0.05$). The organic matter content was higher at 15cm and 45cm in the CA plot yet in the CF plot it decreased with depth. The average organic matter content of 7.82% in the CA plot and 5.80% in the CF fit perfectly within the range of 1 – 6% which is a normal content level (Geocities, 2009). However, the absence of a universal critical or ideal value for content of organic matter content in soils under CA makes it difficult to draw conclusions on the significance of the findings made in this study. This makes Smaling, *et. al,* (1997) and Singh *et. al.,* (2011) observations made above relevant to explain the soil organic matter content in the two plots at Shewula in Swaziland.

5.5.2 Site Testing and Validation Unit 2

There was difficulty to achieve adequate soil cover in the CA plot at the TaVU 2 site. The average soil cover could be referred to as poor at 22.5% since it was significantly lower than the

30% threshold. Evidence of livestock encroachment observed in the CA plot explains the poor soil coverage. The fence erected was found to be at a poor state of repair and concerned farmer admitted to persistent livestock encroachment into the CA plot. Further interviews with the farmer revealed intentions to venture into horticulture which does not require mulch as strictly as it is the case with CA. This farmer was clearly contemplating abandoning CA. This is a common feature among farmers that have adopted CA especially after withdrawal of institutional support to adopting farmers (Mazvimavi *et. al.,* 2010). A significant relationship ($r = 0.919, p < 0.01$) was noted between soil cover and mass of crop residue accumulated. The maximum accumulation of 500g/m^2 noted is higher than anticipated considering the lower soil cover compared to the CA plot in site TaVU 1 which recorded a maximum of 400g/m^2 with higher soil cover. This is attributed to the mass of maize and cow peas which heavier than the combination of maize and jugo beans cultivated in site TaVU 1.

Soil moisture content was slightly higher in the CA plot (13.90%) than in the CF plot (11.90%) at all depths sampled and it increased with depth in both plots. However, the difference in the soil moisture content in plots was not significant and cannot be attributed to either soil cover or amount of residue that has accumulated. Actually, influence of soil cover and amount of crop residue was found to be very weak ($r = 0.117$ *and* $r = 0.267$ *respectively)*. This state of affairs was anticipated due to the poor soil cover in the CA plot which made the conditions more or less comparable to those in the CF plot. But generally the soil moisture content was higher in site TaVU 2 compared to site TaVU 1. This may be attributed to the different soil types; site TaVU 2 being dark to brown loam soil while site TaVU 2 had dark – grey sandy loam soil which has a relatively poor water retention capacity.

The organic matter content declined progressively with depth in both the CA and CF plots. Organic matter content was slightly higher in the CA plot (8.60%) than in the CF plot (8.47%). However, the observed difference between the two plots was not significant ($p > 0.05$) which led a conclusion that there was no influence from soil cover and mass of crop residue on organic matter content especially on the CA plot. Notably, the organic matter content between site TaVU 1 and site TaVU 2 were comparable and there was a weak correlation between soil cover ($r = -0.117$) or *mass* of crop residue ($r = 0.156$) and organic matter in both sites.

5.6 CONCLUSION

Overall results of the study give a clear influence of soil cover and accumulation of crop residue on soil moisture and organic matter content in plots under CA. This is especially the case when considering the significant difference ($p < 0.05$) in soil moisture in both the CA and CF plots in site TaVU 1. However, the organic matter content findings in both sites obscure the influence of soil cover and amount of crop residue on organic matter content. Site TaVU 2 proved problematic in advancing the assumptions of the study due to the poor soil cover of less than 30% due to poor management of crop residue by the concerned farmers. The findings in both TaVUs were anticipated to follow a similar pattern of differences in the values of organic matter and moisture content in CA and CF plots as demonstrated in TaVU 1. But this was not the case as the CA and CF plots in TaVU 2 were both deficient of soil cover. Although confronted with the mentioned limitations the study was able to demonstrate the influence of CA in site TaVU 1 where there was proper management of crop residue in the CA plot. Although the experimental procedures were very basic methods of soil analysis, however the potential value of the study lies in its contribution to the very limited baseline information on CA in the country. Ideally, the study should have included analysis of comparison of nutrient content between soils under CA and conventional farming but this would have made the study too large and difficult to manage hence, this was considered in the study in Chapter 6 below. It is recommended that a logical follow-up to this study is a research focusing on analysis of soil water retention capacity including bulk density and soil compaction on CA plots. The study however raises issues surrounding the use of fencing as a strategy to maintain soil cover. This is an issue since the fencing in the TaVUs all over the country were supplied by the FAO project facilitating the adoption of CA by the local farmers. Since the project ended in 2005 suspicions were rife that farmers may not maintain the fences. Observations made during the study seemed to confirm the suspicions unless the case noted was an isolated one. A question that may need further scrutiny is that of the fate of CA adoption in cases where farmers prevent livestock encroachment in plots under the system and where new adopters cannot afford the fencing materials currently used in the TaVUs.

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CHAPTER 6

THE COMPARATIVE ANALYSIS OF SOIL PROPERTIES UNDER CONSERVATION AGRICULTURE AND CONVENTIONAL FARMING AT SHEWULA IN SWAZILAND.

6.1 INTRODUCTION

Subsistence agriculture is a major source of livelihood to about 70% of the Swazi population that lives in the countryside (WFP, 2013). Local subsistence farmers practice conventional farming techniques under rain fed conditions and are characterised mainly by soil tillage and removal of surface stubble to prepare a “good” seedbed for planting crops (Fowler, 1999). There is a strong tendency towards mono-culture among the farmers especially in the cultivation of maize, the staple crop in Swaziland (Lado *et al.* 2005). The persistent drought experienced in Swaziland since the 1990s, coupled with loss of soil fertility and nutrients through mainly soil erosion and leaching, demonstrated the apparent limitations of conventional farming techniques under rain fed conditions. Poor soil fertility is widely accepted as one of the major factors limiting crop production of small holder farmers in Africa (Sanchez *et. al*., 1997). Maize production in Swaziland has been declining steadily for the past decade. Up until 2000, Swaziland was routinely harvesting more than 100,000 tons of maize per year. Since then, the average harvest has dropped to some 70,000 tons leaving approximately 116,000 people (about 10% of the population) faced with food shortages in the 2012/2013 farming season (Swaziland Vulnerability Assessment Committee, 2010; WFP, 2013). Therefore, food security remains the biggest development goal yet to be achieved by the country.

Therefore, the need for a paradigm shift in the manner subsistence farming is done in the country was noted at the end of the 1990s. Actually, adapting agriculture to a potentially drier future is necessary particularly in the era of climate change (Biello, 2011). In 2000 the government introduced CA as a sustainable agricultural system that maintains and improves soil fertility by among other things preventing depletion of soil nutrients. Moreover CA prevents environmental degradation and increase crop production to realise adequate food for the increasing population (Singh *et. al*. 2011).

Soil is an important medium for crop cultivation and maintenance of its fertility is of paramount importance to farmers. Soil fertility is achieved and maintained in a number of ways which include keeping organic matter and nutrients at adequate level to be accessed by crops. The study was concerned mainly with mineral nutrients particularly macronutrients as these are required in larger amounts by plants than the micronutrients. The focus on macronutrients was mainly on primary nutrients which include nitrogen (N) phosphorus (P) and potassium (K) which are usually lacking from the soil because plants use large amounts of these nutrients for their survival and growth (Muhammad *et. al*., 2005; NACHURS, undated). Secondary nutrients were not of concern to the study since they are usually available in soils in adequate amounts and fertilization is not always necessary (Rowell, 1994; NACHURS, undated). CA liberates these and other nutrients through biological transformations of organic matter in the soil (Doran and Zeiss, 2000).

Nitrogen (N) is a part of chlorophyll, the green pigment of the plant that is responsible for photosynthesis and it helps plants with rapid growth, increasing seed and fruit production and improving the quality of leaf and forage crops. Hence plants deficient of N are stunted in their growth with yellowing (*chlorosis*) of their leaves. Plants use large amounts of N but 97 to 98% of N is unavailable to plants. Only 2-3% of inorganic N in the form nitrate (NO_3^-) and ammonium (NH_4^+) is available to plants. Nitrogen is stored in organic matter and when broken down by microorganisms release either NH_4^+ through *mineralization* (organic N $\rightarrow NH_2 \rightarrow NH_4^+$) or NO_3^- through *nitrification* ($NH_4^+ \rightarrow NH_2^- \rightarrow NO_3^-$) (Rowell, 1994). Opposite to the formation of inorganic N is *immobilization* that somehow maintains a balance in nitrogen cycle in soils. Nitrogen, especially nitrate is lost mainly through leaching from soils (Sawyer, 2007).

Phosphorous (P) is also vital for plants especially during photosynthesis and it promotes, among other things, early root formation, plant growth and seed formation. Plants deficient in phosphorus are stunted in growth and often have an abnormal dark-green colour (Plant and Soil Sciences eLibrary, undated). The study focused on organic P which is added into soil through decaying crop residue and is released from soil organic matter by *mineralization*. For soils where organic matter content is not changing the P content turnover is constant at between 4 and 8kg P ha^{-1} a^{-1} (Woomer *et. al.,*1994). Phosphorous is mainly lost through erosion of the top soil especially due to increased surface run-off (Lory and Cromley, 2006). Therefore, it is assumed that larger amounts of P could be realised where large quantity of organic matter accumulates on top of the soil to be a constant source of organic matter and for prevention of surface run-off on cultivation land. The retention of crop residue inherent in CA could be significant in the accumulation of large amounts of phosphorus in soils.

Potassium (K) of immediate use to crops is the portion of K that is in an exchangeable (available) form for plant use. Potassium is an exchangeable cation. The K ion has a positive charge and binds with the negatively charged soil particles hence K is known to interact with almost all essential plant nutrients and essential for plant enzyme activation, efficient use of water, photosynthesis, starch formation and crop quality (Plant and Soil Sciences eLibrary, undated). Potassium is absorbed by plants in larger amounts than either magnesium or calcium with the exception of nitrogen (N). Potassium is unique because it does not become part of plant compounds, but remains in ionic form in the plant. Potassium remains in plant residues after harvest and in manure and may be easily lost through crop removal and leaching. Accumulation of crop residue as inherent in CA helps maintain a steady supply of K and prevents its loss in the manner mentioned above.

Conservation agriculture is regarded as a system that involves several techniques that revolve around zero tillage and accumulation of crop residue (for soil cover) (Dumanski *et. al.*, 2006; Derpsch and Friederich, 2010). Under the system crops are cultivated through intercropping and crop rotation while direct application of seeds is common (CGIAR, 2011; FAO, 2011a). In Swaziland practice of CA involve all the techniques mentioned above (SADC ICART, 2009). The retention of crop residue inherent in CA is viewed as important in keeping nutrient content within the rooting depths of most grain and legume crops. Moreover, the system helps in the accumulation of soil nutrients over time thus enhance soil fertility and stability (Dumanski *et. al.*, 2006). Conventional farming, on the other hand, is viewed as wasteful and results in increased surface run-off, decrease of soil micro-organisms and large-scale loss of organic matter which is a source of soil nutrients.

Despite the noted benefits of CA over CF very few farmers have adopted the system since its introduction in the country in 2000 (Mlipha, 2010). Despite efforts from Government and partner organizations such as FAO and COSPE (Co-operation for the Development of Emerging Countries) the adoption of CA at Shewula, for instance, remained at about 5% after ten years the system was introduced in the area (Chapter 4). The low adoption rate is attributed mainly to lack of locally generated information about the performance of the system in Swaziland (Dlamini & Masuku, 2011). In the absence of such information it is difficult to influence the farmers and change their mind set which is currently rooted on conventional farming techniques. The local farmers therefore fail to relate to the system of farming as it applies to local situations. Therefore, the study was intended contribute empirical evidence about the performance of CA especially its impacts on improvement and retention of soil fertility. The study compared soil pH and nutrient content levels between soils under CA and CF. The study was driven by the assumption that nutrient levels were significantly higher in soils under CA than in those under CF.

6.2 THE STUDY AREA AND SITE

6.2.1 Description of Shewula

The study was carried out at Shewula, a rural settlement situated in the northern-eastern part of Swaziland on the Lubombo plateau at about 500 metres above sea level (Figure 5.1 on page 103). It lies along Longitude 32° 00’ and 32^o east and Latitude 26° 03’ and 26^o 09’ south. The area is relatively dry with a long term annual average rainfall of 700mm, which it has failed to reach for past 10 years due to persistent drought gripping the country. Day time temperatures are generally warmer in summer averaging about 27°c and cool winter averaging about 10°c. Shewula is characterised by a rugged escarpment terrain and indigenous woodlands stretching along the Mbuluzi River. The soils are predominantly *lithosols* dominated by shallow grey loam resting on hard rock and the young shallow brown-black loam to clay soils. Shewula experiences persistent drought spells which have significance effects on the production of food crops such as maize yet 80% of the approximately 10, 000 people of Shewula area depend on rain fed subsistence farming for their livelihood. The remainder is engaged in wage based employment in the neighbouring commercial sugar-cane plantations and private farms. Maize, being a staple food, is grown on a wide scale at Shewula and the yields are reflective of the national situation as they are continuously declining due to the persistent drought, lack of tractors and animal traction, limited access to agricultural inputs and impacts of HIV/AIDS (Save the Children Fund, 2003; Mlipha, 2004; IRIN, 2012; WFP; 2013). There are a variety of other crops grown including traditional crops such as jugo beans, cassava, pearl millet to name a few, albeit on a small scale (Mlipha, 2004).

6.2.2 The Study site

The study was conducted in the Testing and Validation Unit (TaVU) located in the Bucocantfombi sub-area in north western part of Shewula (Figure 5.1). The TaVU has a plot under CA existing alongside plots under CF. The plot under CA was fenced to prevent livestock encroachment while those under CF were not fenced and the CF plot closest to the CA plot was treated as a control site for the study. The plot under CA had an east-west orientation with a slope angle of between 8^o to 10^o. It was scalene triangular shape with base of 70m and sides with 46m and 50m. The plot under CF had a similar orientation and slope angle to the adjacent plot under CA. It had a 113m length and 50m width.

6.3 METHODS AND SAMPLING

6.2.3 Sampling

The study was conducted in the spring season of 2013 when farming commences among subsistence farmers. Soil samples were collected in both the CA and CF plots in 10 sampling points. Grid squares with 12.5m x 10m were marked to facilitate selection of sampling points. Since the plot under CA was small 10 sampling points were produced while demarcating the grid squares hence there was no need to sample. In the CF plot a 20% sample of grid squares was selected to produce 10 sampling points.

The grid squares, located at regular intervals in linear pattern, made the systematic random sampling method ideal for selection of sampling points. To overcome some of the shortcomings of the sampling method noted by Dixon & Leach (1977) the first sampling point in each row was selected using a table of random numbers and thereafter every 5^{th} grid was selected to constitute the sample. The sampling points were located at the centre of the grid squares. A larger number of sampling points of 25 are ideal in a soil survey but Rowell (1994) mentions that sampling points less than 25 are also acceptable especially in small plots as it is the case with those studied at Shewula. In all, soil sampling was conducted in 20 sampling points in both CA and CF plots.

6.2.4 Collection of soil samples

Soil samples were collected from the sampling points located at mid-points of the selected grid squares. Due to limitations in the use of hand driven soil augur, sampling at depths beyond 45cm was difficult. Therefore, sampling was done at depths of 20cm and 40cm instead of the planned 15cm, 30cm, 45cm and 60cm. The maximum sampling depth of 40cm may appear shallow considering that some crops have roots as deep as one metre and considering that some studies sampled as far deep as 80 cm using the Anderson and Ingram's (1993) sampling procedure. However, it was noted that 90% of roots of most crops are in the top 60cm of soil depth and most of the lateral roots for nutrient uptake are concentrated in the 30cm depth (Northwest Bean Growers Association, 2007). Moreover, only 10% of crop water and nutrient uptake happen below 60cm (NDSU, 1997; Northwest Bean Growers Association, 2007). Collected soil samples were stored and transported in clean (new) plastic sampling bags to prevent contamination.

6.2.5 Soil Analysis

Determination of pH, organic matter and phosphorous

The analyses were conducted at the University of Swaziland in the Faculty of Agriculture following analysis procedures from Motsara and Roy (2008).

Determination of Nitrogen and Potassium

The analyses were done by Intertek Testing Services in Johannesburg, South Africa. The *NO3-N* extractable inorganic nitrogen (*KCl)* and *K* – Ammonium acetate extractable methods used were derived from the AGRILASA Soil Handbook (2004).

6.4 RESULTS

6.4.1 Soil pH and Organic matter content

The soils were generally acidic with pH of about 5 in both the CA and CF plots which is below the 7.0 marking the neutral point (Table 6.1). The soil acidity increased with depth though slightly. The organic content was about 5.0% in both farming systems and showed a tendency to decrease slightly with increase in depth. There appeared to be similarities in organic matter content between the two farming systems however CA seems to maintain higher organic matter content at increased depths compared to conventional farming.

Table 6.1 Soil pH and organic matter in conservation agriculture and conventional farming plots at 20cm and 40cm depth

Type of farming & depth	Soil pH	Organic Matter (%)
CA plot at 15cm	5.08	5.53
CA plot at 40cm	5.01	5.41
CF plot at 15cm	5.25	5.59
CF plot at 40cm	4.91	5.26

6.4.2 Nitrogen

The study considered Nitrogen as nitrate (NO3-N) but not Ammonium. This was due to constraints in availability of testing equipment. Figure 6.1 below indicates that at 20cm the nitrate content in both CA and CF plots was about $14mg/kg^{-1}$ with the CF plot having a slightly higher content at $15.41mg/kg^{-1}$ than the CA plot with $13.68mg/kg^{-1}$. However, the difference in nitrate content between the two farming systems was not significant ($p > 0.05$). A big variability was noted in nitrate content across the plots. The CA plot recorded a minimum nitrate content of about 5mg/kg^{-1} in sampling point 10 and maximum of 27mg/kg^{-1} in sampling point 1. In the CF plot the minimum nitrate content was 4.31mg/kg^{-1} also in sampling point 5 and maximum of 31mg/kg^{-1} in sampling point 7.

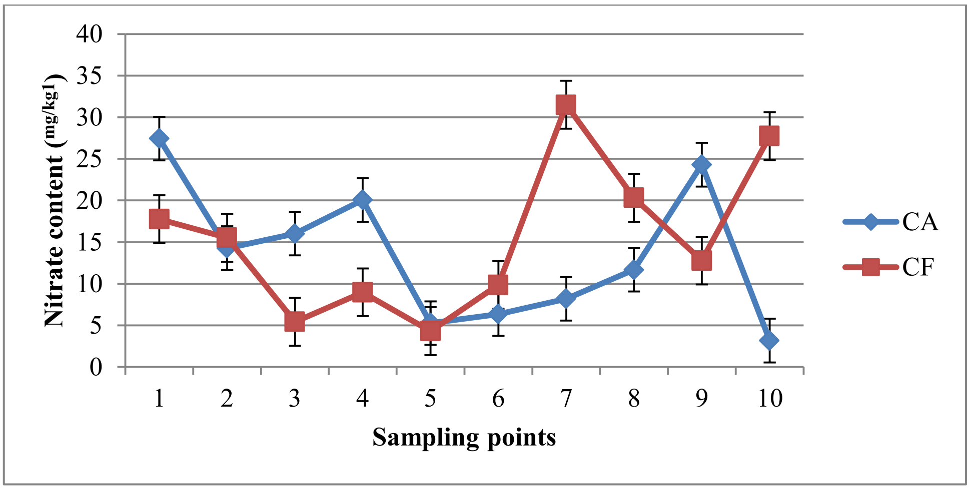

Figure 6.1 Nitrate content at 20cm depth in conservation agriculture and conventional farming plots

At 40cm average nitrate content was slightly higher in the CA plot at 13.68mg/kg^{-1} than in the CF plot where it was 11.72 mg/kg^{-1}. However, the difference in nitrate content between the two farming systems was not significant ($p > 0.05$). The lowest nitrate content in the CA plot was 4.17 mg/kg^{-1} in sampling point 5 and the highest was 27.34 mg/kg^{-1} in sampling point 1. The lowest nitrate content in the CF plot was 3.69 mg/kg^{-1} in sampling plot 3 and the highest was 19.63 mg/kg^{-1} in sampling point 4 (Figure 6.2). Sampling point 7, 8 and 10 high nutrient content in the CF plot due to position of the points at the basement of the plot where eroded soil material from the plot accumulates. The deposited material included organic matter laden with nitrates. Sampling 4 point is an outlier indicating exaggerated increase of nitrates with depth.

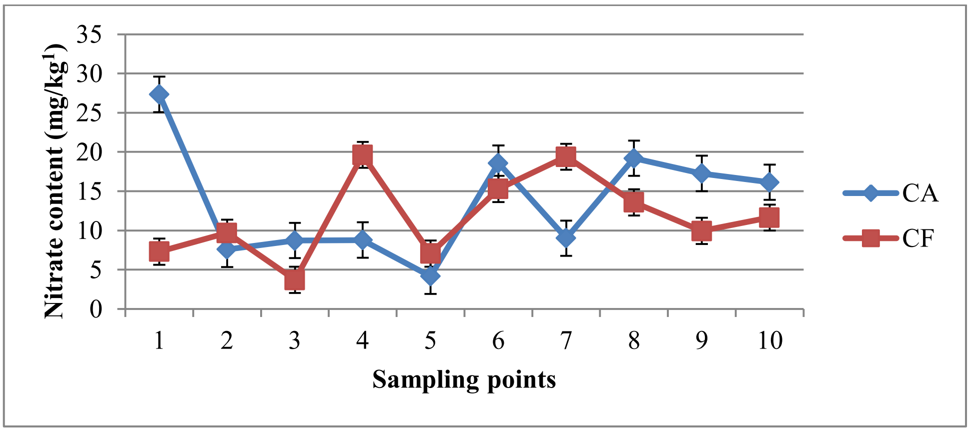

Figure 6.2 Nitrate content at 40cm depth in conservation agriculture and conventional farming plots

Overall the nitrate content on both plots was higher than the recommended minimum level of 6mg/kg^{-1} at 0 – 60cm soil depths (Peng *et. al*., 2013). Figure 6.3 below indicates that the nitrate content in both plots was at 20cm depth was higher in the CF plot (16.13 mg/kg^{1}) compared to the plot under CA (15.01 mg/kg^{1}). The nitrate content decreased in both plots at 40cm depth. However, the nitrate content was higher in the CA plot (13.25 mg/kg^{1}) than in the plot under CF (12.03 mg/kg^{1}). The higher nitrate content is attributed infiltration of decomposed crop residue laden with nitrate to depths deeper than 20cm. However, the difference in nitrate content in the two plots was not significant (*p > 0.05*). The results indicate that the plot under CA created larger amounts of nitrates through accumulated organic matter that infiltrated the soil to levels below 20cm.

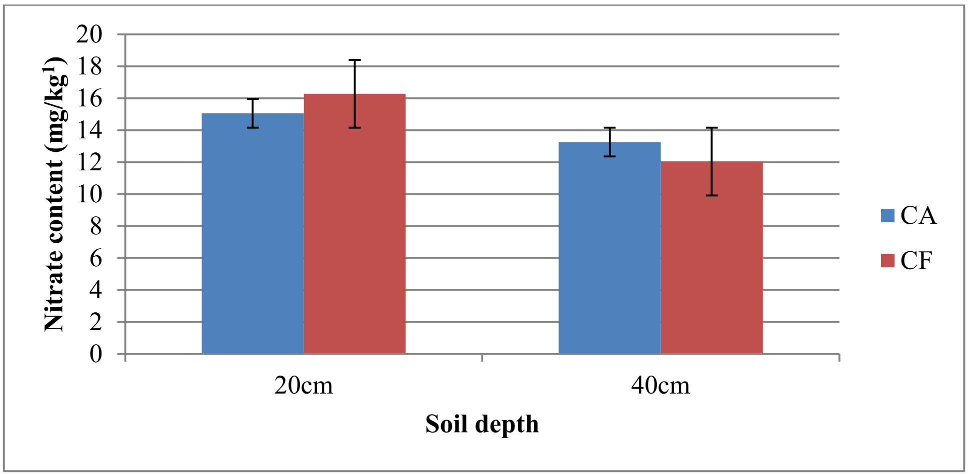

Figure 6.3 Average nitrate content in the conservation agriculture and conventional farming plots

6.4.3 Phosphorus content

Figure 6.4 below indicates that there was low phosphorus content at 20cm in both farming systems in all sampling points. On average the content was about 10mg P kg^{-1} far less that the critical value of 15mg P kg^{-1} as indicated by the Department of Sustainable Natural Resources (undated) and Woomer *et. al.,* (1994).

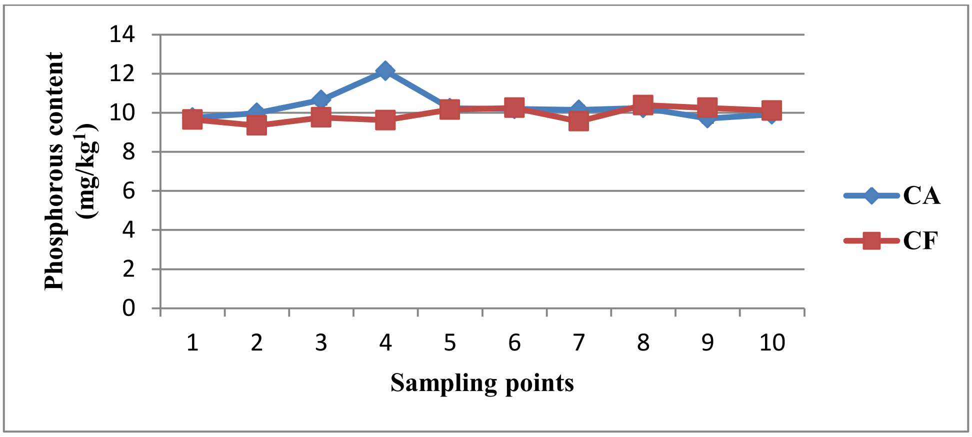

Figure 6.4 Phosphorous content at 20cm depth in conservation agriculture and conventional farming plots

At 40cm the P content was also lower in both farming systems with an average of above 9mg P kg^{-1} below the P critical value of 15mg P kg^{-1} noted above. P values recorded in the sampling points were more or less similar except sampling points 2, 3 and 10 under CA which recorded values higher than those in the plot under CF (Figure 6.5).

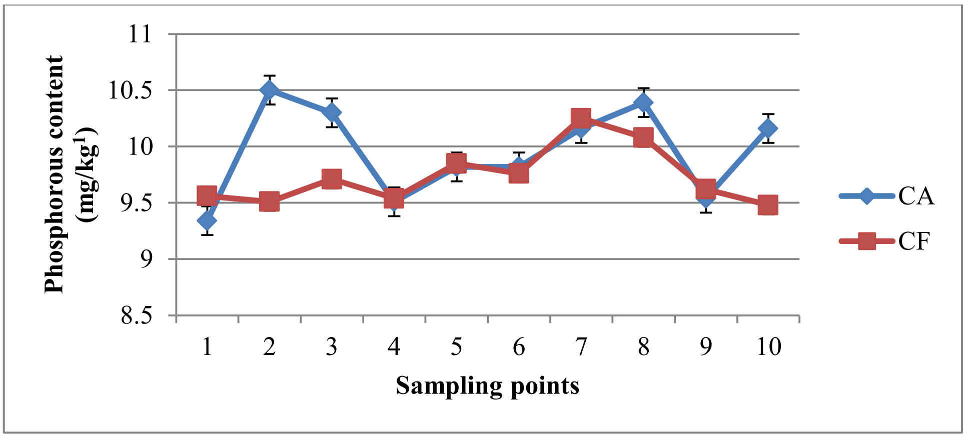

Figure 6.5 Phosphorous content at 40cm depth in conservation agriculture and conventional farming plots

The average P values for the two plots were lower than the critical P value in all depths. However, the P value in the CA plot was relatively higher than that of the CF plot in both 20cm and 40cm depths but the difference between the two was not significant ($p > 0.05$) (Figure 6.6). P values were higher in the 20cm depth and decreased with depth in both cases implying less availability of phosphorous to crops in depths lower than 40cm.

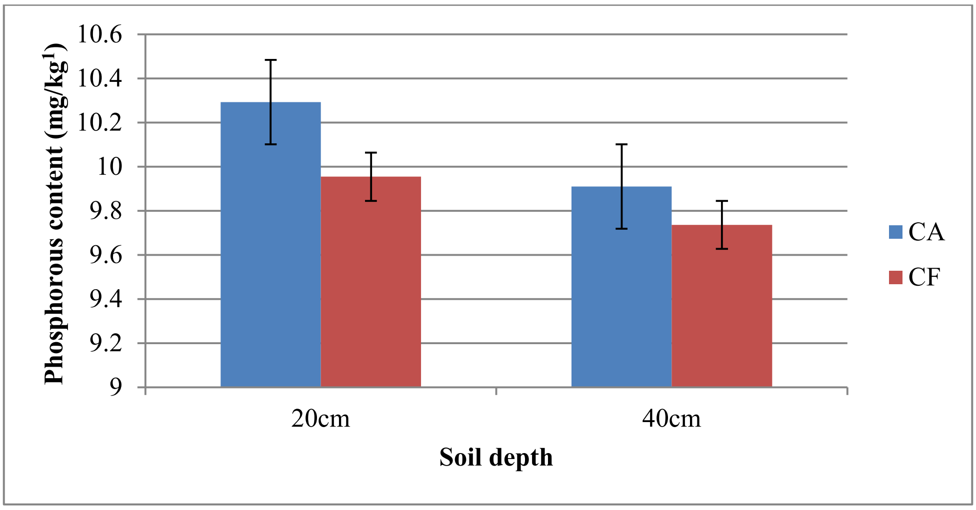

Figure 6.6 Average phosphorous content in the conservation agriculture and conventional farming plots

6.4.4 Potassium content

At 20cm the level of exchangeable K was high in both farming systems as it was above the critical value of 0.25cmolc/kg^{-1}for maize at CEC (cations exchange capacity) 10meq/100g). Both Olsen and Mehlich identified 0.20cmolc/kg^{-1} of K as critical value below which maize would perform badly (Woomer, *et. al*., 1994). Potassium values were slightly higher in the CA plot that the CF in almost all the sampling points (Figure 6.7). On average exchangeable K in the CA plot was slightly higher at 1.30cmolc/kg^{-1} than in the plot under CA at 1.06cmolc/Kg. However, the difference of K in the two plots was not significant (*Levene's test 0.989, $p > 0.05$*).

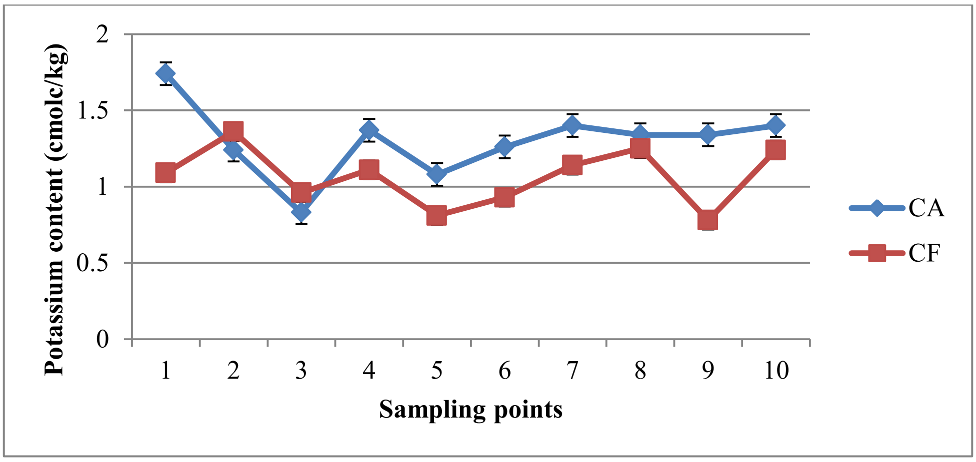

Figure 6.7 Potassium content at 20cm depth in conservation agriculture and conventional farming plots

At 40cm exchangeable K content showed a decrease but still above the critical value of K for maize at CEC 10meq/100g. The average K value was significantly higher ($p < 0.05$) in the CA plot than in the CF plot (Figure 6.8). On average the CA plot had 1.04 cmolc/kg^{-1} content compared to 0.41 cmolc/kg^{-1} in the CF plot. At sampling point 1 the K content level under CA was higher (1.39 cmolc/kg^{-1}) than the average K content for all the sampling points in the plot. This may be attributed to its location at the centre of the field on entry to the plot. It is assumed that it benefited from unequal distribution of manure applied by the farmer. Soil test for K was lower in some parts of the CF plot especially in sampling points 3, 5 and 6 where it was below the critical value for K. In the CA plot soil test for K was consistently higher than the critical value for K in all the sampling points. This indicates that CA is able to maintain higher K content levels at increased depths compared to CF.

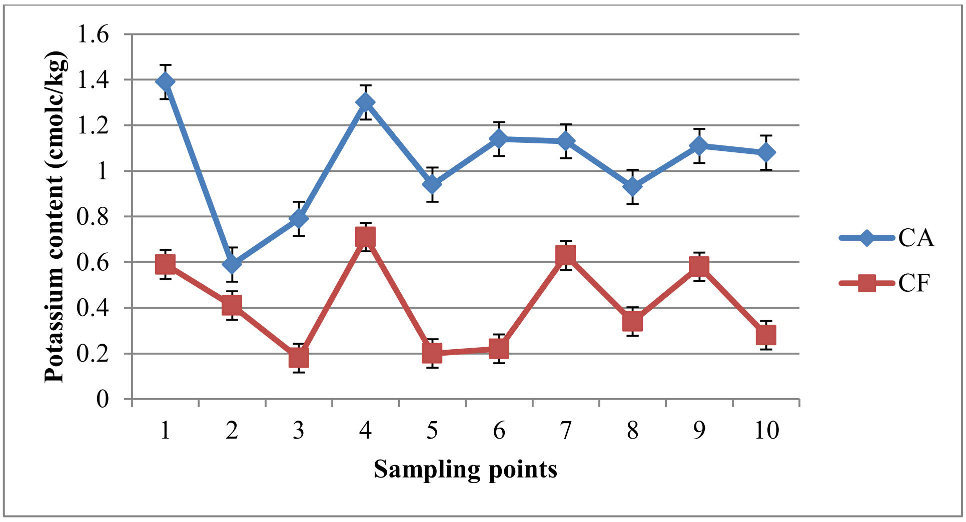

Figure 6.8 Potassium content at 40cm depth in conservation agriculture and conventional farming plots

Overall the K content levels were higher in the CA plot than in the CF plot in both 20cm and 40cm depths (Figure 6.9). However, the difference in the K content values between the two farming systems was not significant ($p > 0.05$). The potassium values were also above the critical soil nutrient K content. In both farming systems the K content values decreased with increase in soil depth making less K availability to crops at depths lower than 40cm.

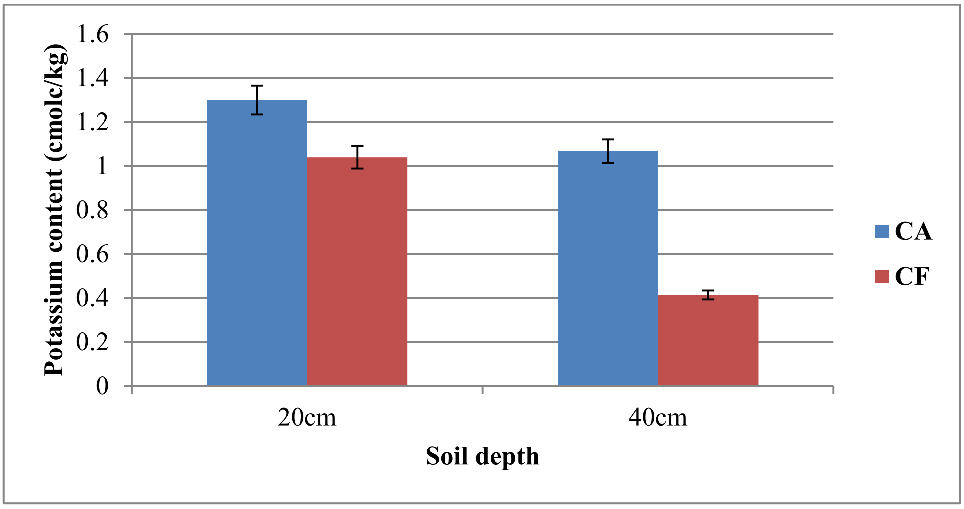

Figure 6.9 Average potassium content in conservation agriculture and conventional farming plots

6.5 DISCUSSION

Low soil fertility status of most tropical soils hinder maize production as it is characterized by a strong exhausting effect on soil nutrients (Law-Ogbomo and Law-Ogbomo, 2009). Various ways and nutrient levels are used to estimate the soil fertility status. For instance, the soil organic carbon (SOC) is used as an index for soil fertility in Southern Africa (Woomer *et. al.,* 1994). Moreover, soil fertility evaluation in the region rely on ascertaining soil nutrient levels mainly N, P, K; referred to as primary nutrients in the macronutrients category and they are required in greater amounts by crops (Rowell, 1994; NACHURS, undated). SOC, secondary nutrients and micronutrients are considered to a lesser extent since they are either readily available in the soil or are required by plants in small amounts. Hence the study focused on N P K as well as soil pH and organic matter.

Availability of soil nutrients to plants is limited by low pH values rendering the acidic soils infertile to support higher yields (Mckenzie, 2003; Extension, 2011). Nutrients activity is slowed down in pH levels less than 6.0. That is why soil pH levels within 6.5 and 7.0 were established as the best range for most crops to grow (Mckenzie, 2003). At Shewula the soils, at a pH of about 5, were acidic in both the CA and CF plots. Therefore, soil pH was viewed as a limiting factor for plant growth amid the problem of stunted plant growth and poor yields noted by the farmers in both farming systems. To correct the situation it is necessary for the farmers to first address the soil acidity problem through application of lime before application of fertilizers.

Conservation agriculture contributes to soil fertility through maintenance and addition of soil nutrients compared to CF. Conservation agriculture liberates plant nutrients through biological transformation of organic matter (Muhammad *et. al.,* 2005). Conservation agriculture techniques involve retention of crop residue for accumulation of organic matter which is the main source of most of soil nutrients (Rowell, 1994; Lory and Cromley, 2006; Lewandowski, 2013). Moreover, zero tillage, retention of crop residue and intercropping ensure that loss of nutrients is prevented as all the nutrients are commonly lost through removal of crop residue, leaching and surface run-off (Oelmann, *et. al*., 2007); Sawyer, 2007; Lory and Cromley, 2006; Plant and Soil Sciences eLibrary, undated). At Shewula the soil nutrient content was higher in the CA plot compared to the plot under CF. Potassium content was significantly higher ($p. < 0.05$) under CA at 40cm depth than under the CF plot. Potassium content was average 1.04cmolc/kg^{1} compared to 0.41 cmolc/kg^{1} in the CF plot (Figure 6.9). The differences in content of the other nutrients between the farming systems were not significant ($p. > 0.05$).

Nitrogen is one of the most important nutrients for plant growth while it is also the most deficient in highly weathered tropical and subtropical soils leading to reduction of crop yields (Mkhabela *et. al*., 2001). At Shewula high levels of nitrate content exceeding the critical value of 6mg/kg^{-1} on both farming systems were obtained. The nitrate content under the CA plot was higher (15 mg/kg^{1}) in the 40cm depth compared to CF where it decreased to about 12 mg/kg^{1}. There was no significant difference ($p. > 0.05$) in nitrate content in soils under CA and CF plots despite that the content was slightly higher in the CA plot at 40cm depth. Mainz *et. al*., (1993) found increased nitrate concentration in greater soil depths and they classified this as rare accumulation of unused nitrogen. The higher nitrate levels in both farming systems could be attributed to the continuous cultivation of cowpeas alongside maize for past 10 years. The farmer did not apply fertilizers in both plots for a long time. The slight depletion of nitrates in the 20cm depth may be attributed to efficiency of maize in the uptake of nitrates which is common in the depths up to 60cm (Mainz *et. al*., 1993). The soil test for N at Shewula is still at a healthy level and farmers need to regularly check that the test does not drop below the critical level where it will require fertilizer application.

Low values of phosphorous were obtained in both the CA and CF plots. On average the phosphorous was 10 mg P kg^{1} far lower than the critical value of 15mg P kg^{1}. Although the P values in the plot under CA were slightly higher than P values in the plot under CF but the difference in the P values of the two farming systems was not significant ($p. > 0.05$). This finding appears to downplay the influence of CA in the maintenance of higher phosphorous concentration in the soil. The low P values noted in both systems of farming might be due to the acidic nature of the soils as the nutrient P is dependent on the soil pH status. Moreover, the low level of stubble accumulation noted in the CA plot and the continuous tillage and removal of stubble in the CF plot constrained natural replenishment of phosphorous. Phosphorous, like potassium, is continuously removed by plants every farming season and some is subsequently lost if crop residue is removed (Camberato and Joern, 2008). Without phosphorous application, as it is the case with the CA and CF plots studied, the soil test for P dropped to levels below the critical level. During *ad hoc* interview the farmer complained about the maize crop being stunted and showing dead patches on its leaves. These are all symptoms of phosphorous deficiency.

High values of potassium above the critical level for K were observed in both farming systems. However, higher values of potassium were noted in the plot under CA than under CF though the difference in K values in the two systems was not significant. The higher values in the plot under CA might be due to the crop residue that is retained in the practice of CA. By its nature Potassium remains in plant residues after harvest and its retention ensures continuous replenishment of potassium in the soil. That could be the reason why potassium content in the plot under CA is relatively higher. In the plot under CF higher potassium concentration was maintained by application of poultry manure done by the farmer annually. Livestock manure, especially poultry, when applied correctly, contributes large concentrations of soil nutrients especially potassium (Tucker, 1999; Javeed *et. al*., 2013). The farmer mentioned that the manure was not applied in the soil under CA yet it still obtained higher values than the soil under CF. In a way, this confirms the contribution of CA in the building and maintenance of higher levels of potassium concentration in soils.

6.6 CONCLUSION

It must be noted that the study was performed under some limitations of capacity especially in soil sampling and laboratory analysis. There was a challenge of extracting soils beyond 40cm using the hand driven soil augur in the dry spring period. This was the main challenge that limited the study to only two sampling depths of 20cm and 40cm. Ideally; the intention was to sample at 15cm, 30cm, 45cm and 60cm. Moreover, only soil pH, organic matter content and phosphorous concentration were conducted in the institutional laboratory. The rest of the tests were conducted at Intertek, a private laboratory in South Africa. For accuracy and creation of meaning in the findings the study would have benefited from a longer period of study beyond the one year over which this study was conducted. However, the one year period of study did not affect the validity of the findings as it was observed in a similar study by Law-Ogbomo and Law-Ogbomo (2009).

Despite the mentioned limitations the study was able to make significant findings about the influence of CA in the improvement and maintenance of nutrients in cultivated soils. The retention of crop residue and zero tillage, inherent major features of CA, did not have any significant influence on the soil pH, organic matter content and concentration of nitrate and phosphorous in the soil. The pH and levels of nutrient concentrations between soils under CA and CF did not show significant differences though the values were slightly higher in the soil under CA. The P values obtained in both farming systems were low compared to the critical level for P. This was attributed mainly to the acidic nature of the soils.

Therefore, the influence of CA in the soil pH and obtained values of nutrient content as mentioned above was not significant though demonstrated tendency to be slightly higher in the CA plot. The influence of CA was only observed in the potassium concentration particularly at 40cm where the difference in values obtained for the two systems were significantly different. However, the mean potassium content, though higher in the plot under CA, did not show a significant difference between the two systems. However, potassium values obtained were higher than the critical level for K in all the farming systems. This was attributed to retention of crop residue and annual application of livestock manure.

Nutrient concentrations tended to decrease with increase in depth. This common trend limits plant access to nutrients in depths below 60cm. However, this was not the case with nitrogen as its concentration increased at 40cm exceeding the concentration at 20cm. Mainz *et. al*., (1993) made a similar finding where nitrate concentration increased at 60cm depth. They attributed this situation to efficiency of maize in the uptake of nitrate at depths up to 60cm and accumulation of unused nitrogen in depths 60cm to 90cm. The presence of nitrogen in lower depths favours crops with longer roots like sorghum that can tap into nutrients in depths below to 60cm. In the final analysis, maintenance of balance in nutrient content is important. Nutrient uptake by plants and due to other losses must be replenished to maintain a balance because oversupply and undersupply of soil nutrients has negative consequences (Maro, *et. al*., 2008). In addition, the potential of CA to influence higher concentration of nutrient content in soils is apparent if the findings of the study are anything to go by. The plot under CA had consistently higher nutrient values than those of the CF plot despite that the two plots shared similar characteristics including, among others, soil qualities, climatic conditions and types of crops cultivated. The only difference between the two plots was the farming systems. The lackluster performance of

CA to have higher nutrient content compared to CF could be attributed to lack of achievement of basic tenets of CA which include adequate soil cover and accumulation of crop residue. Inadequate soil cover exposed the soil to surface run-off which is detrimental nutrient concentration. The inadequate accumulation of crop residue limited the creation of a constant reserve for organic matter which is the source and store of soil nutrients.

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CHAPTER 7

GENERAL CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

This chapter reviews the findings made in the various components of the study presented above and draws relevant conclusions aligned to the objectives of the study as outlined in Chapter 1. The chapter presents some recommendations emanating from the findings of the study that may also facilitate the adoption of CA in the country. The main focus of the study was on conservation agriculture (CA) with particular attention to its adoption and influence in the improvement and maintenance of soil moisture and fertility. Conservation agriculture is viewed as a farming system that involves various techniques aimed at minimizing soil disturbance while protecting it from degradation as well as conserving its basic properties and structure (FAO, 2011; Hobbs *et. al.,* 2008; Dumanski *et. al.,* 2006; Derpsh, 2005; Landers, 2001). As noted above, paramount to the practice of CA in Swaziland is zero tillage, retention of crop residue as well as adoption of cropping patterns such as crop rotation and intercropping (FAO, 2006; Derpsch, 2005). These CA techniques are essential for soil and water conservation while building a stable structure for sustainable crop production and diversity (FAO, 2008). Conservation agriculture was introduced in Swaziland at the beginning of the 21st millennium and was intended for adoption mainly by small-scale subsistence farmers; yet in Latin American countries and South Africa CA is practiced mainly by large scale commercial farmers. Among the benefits of CA noted above, especially the zero tillage is the significant reduction of cultivation costs which makes the system relevant to the resource poor subsistence farmers in Swaziland. Moreover, the system's ability to conserve soil moisture and nutrient content, (as established in chapters 5 and 6 above), was viewed as beneficial to smallholder farmers with limited access to irrigation and finance for acquisition of fertilizers such as those at Shewula in Swaziland.

7.2 GENERAL CONCLUSIONS

The study was able to document the introduction of CA in Swaziland as well as the various contexts in which the system was introduced. The CA's introduction was against a backdrop of increasing food security concerns in the country where slightly more than 10% of the population experience food (maize) shortage amid continued national failure to achieve self-sufficiency in maize production and supply to people (Magagula *et. al.,* 2007; National Maize Corporation, 2010; Swaziland Vulnerability Assessment Committee, 2010; IRIN, 2012). The study established that the prospects of adoption of CA in Swaziland were quite significant owing to the involvement and commitment of government and its partner agencies to facilitate the adoption of the system in the country. Moreover, the performance of CA in reducing cultivation costs and improvement of soil fertility (as noted in the Testing and Validation Units) demonstrated the system's potential benefits to farmers. However, some formidable challenges were identified by the study with a potential to curtail the promising prospects of its adoption. The major challenges, as previously stated, include problems of management of the crop residue and maintenance of soil cover, lack of tools relevant for CA practice, shortage of labour for initiating the practice of the system and the prevailing mindset among local farmers which remains rooted on CF practices. Nevertheless, the shortage of local information on the practice and performance of CA was viewed as a serious challenge to the adoption of the system in the country. The study recommended that the identified challenges be addressed timeously to enhance the prospects of adoption of CA in Swaziland. As noted above, the study of the challenges and prospects of adoption of CA in Swaziland lacked empirical evidence and this was due to a culture of not keeping farming records which is common among local subsistence farmers. The deficiency of baseline data owing to lack of farming records among the farmers affected all the components of the study. It is therefore recommended that record keeping be introduced among the local farmers to monitor and evaluate national achievements in the development of smallholder subsistence agriculture. This would need to be introduced through the extension officers with well-publicized support from the Ministry of Agriculture.

The FAO project supporting the introduction of CA in the country rallied around the promotion of cultivation of traditional of crops by the local subsistence farmers, based on the notion that these seed strains are relatively drought tolerant and have high nutritional value (Mlipha, 2004). Moreover, farmers were encouraged to practice intercropping and crop rotation as basic techniques of CA. The study established that the farmers were cultivating a limited range of predominantly traditional crops. As established in chapter 3, a majority of the subsistence farmers cultivated predominantly traditional maize and sorghum cultivars because of their ability to withstand drought. The study does not in any way equate the cultivation of traditional crops to adoption of CA but the interest on traditional crops was driven by the fact that the promotion of their cultivation was used by the project introducing CA as a medium for facilitating adoption of the system by the local farmers. It was noted in Figure 3.3 that most farmers produced their own seed or acquired seed locally especially from either neighbours or relatives. This is a significant state of affairs and the study recommends increased cultivation of traditional crops owing to, among other things, their tolerance of drought and pests instead of resorting to genetically engineered (GE) seeds. The most common cropping pattern among the farmers was intercropping where 81% of the farmers dedicated their entire land to the intercropping especially of maize with any other crop but commonly pumpkins. These were significant findings pertaining to the adoption of CA because intercropping is one of the basic tenets of the system. Though the data was not conclusive pertaining to purposes for cultivation of some crops besides consumption however it emerged that legumes and traditional maize were cultivated for their ability to withstand drought. This meshed well with the context in which CA was introduced in the country, where drought was threatening the livelihoods of about 70% of the Swazi population. The study concluded that the cultivation of traditional crops (though directly linked to CA as noted above) and practice of intercropping were significant to the adoption of CA because they were integral in the introduction of CA in the country besides zero tillage and retention of crop residue. It has, however become clear during the study that these two concepts need to be kept distinct from one another.

The involvement of government in facilitating adoption of CA and practice of some basic principles of the system enhanced the likelihood of its adoption by the local farmers. In 2010, ten years after the introduction of the system, it was imperative for the study to ascertain the level of adoption of the system by local farmers as one of its specific objectives. A survey involving 313 farmers (30% sample of the adult population) at Shewula revealed a low level of adoption of conservation agriculture at Shewula. As noted in chapter 4 only 4.8% of the farmers practiced the system and the rest were either willing (65.5%) or not willing (29.7%) to adopt the system. The pattern of adoption established indicates that farmers practicing the system were mostly women. Moreover, most of the farmers practicing CA were aged between 30 and 59 years with no adoption among famers in their 20's and in the over 60 years' group. The young farmers lacked farming experience required to venture into new farming techniques while older farmers above 60 years were mainly conservative and cautionary in their approach to farming mainly to avoid risks they associated with adoption of new farming techniques. Adoption was also found to be higher among farmers with formal education from primary to high school levels. The study established that slightly more than 50% of the farmers lacked awareness and knowledge about the system and this was mainly attributed to lack of information about the system.

The lack of awareness and knowledge about CA does not apply to all CA techniques but mostly to zero tillage and the retention of crop residue. The study observed that farmers were perturbed by cultivation that did not involve tillage and which encouraged accumulation of crop residue. Conventionally, the farmers have been advised that soil tillage helps prepare a proper seed bed for seed planting and also removes weeds and diseases left by the previous crop. However, the study established that the local farmers were quite familiar with minimum tillage, an important CA technique, as they traditionally used simple tools (for example sharpened stones and sticks, the hoe to name but a few) to prepare the soil for seed planting and weeding without soil tillage. Moreover, intercropping and crop rotation were found to be familiar to local farmers as noted in chapter 2. Therefore, farmers lacked knowledge about the significance of zero tillage and retention of crop residue in crop cultivation. In the case of Swaziland, it is suggested that the introduction of CA and the promotion of its adoption must concentrate and reinforce the CA techniques familiar to the farmers and use awareness raising campaigns on the significance of zero tillage and retention of crop residue. Perhaps the promotion of cultivation of traditional crops in the introduction of CA was along the same notion of helping farmers adopt CA along a medium (traditional crops) that is familiar to the farmers.

The low level of awareness and knowledge about CA was also noticed on the motivation or lack of it to adopt the system. Farmers practicing CA were motivated mainly by its benefits and advantages over CF whereas those not practicing the system were discouraged by perceived disadvantages they associated with the system. But most of the respondents were doubtful about the performance of a farming system that did not involve tillage of the soil. The study concluded by expressing the need to raise awareness about CA and capacitating farmers who have adopted the system with critical information and training skills to train other farmers and thus accelerate the adoption rate of CA.

Provision of local information about CA was deemed crucial to facilitate its adoption of the system by the local farmers. However, such information requires research to be conducted on all facets of the system as practiced by the local farmers. It was imperative for the study to contribute empirical information about the performance of the system in areas that are of immediate concern to the farmers which include stabilization of soil pH, improvement of soil moisture and organic matter content. Farmers perceived ideal soil pH as well as improved soil moisture and nutrient content as crucial in the pursuit of crop cultivation in the prevailing drought. Admittedly, the study of the soil parameters mentioned above was a precursor to future elaborate and intense research on soil nutrient content and other parameters. The study established that the famers practicing CA were able to achieve adequate soil cover and accumulation of crop residue in one of the CA plots. However, this was not the case in one plot under CA where due to poor management of crop residue the soil cover was below the recommended minimum of 30%. The study concluded that CA, where practiced correctly, result in soils that have adequate soil cover to prevent soil erosion. Moreover, the soil cover guarantees conservation of soil moisture through prevention of evaporation and continuous decomposition of the accumulated provides a constant source for soil organic matter which is a source of critical macro and micro nutrients. This conclusion is based on the findings acquired from the TaVU 1 where the values of all the parameters measured in the CA plot were higher than those in the CF plot. The situation in TaVU 2 could not be of help to the study due to the observed poor maintenance of soil cover and crop residue. The availability of soil moisture, in particular, as a benefit accruing from practice of CA is of immediate significance to the local farmers in the context of the persistent drought.

Pertaining to soil nutrients the study noted the problem of acidity in soils under both farming systems which affected nutrient content especially phosphorous. Variability was observed in the various sampling points within the plots but on average the nutrient values were consistently higher in the plot under CA compared to that under CF. Though the difference was not significant in the nitrate and phosphorous content but it was found to be significant in the potassium content especially at 40cm depth. The nitrate and potassium content in soils under both systems was higher than the established critical levels but phosphorous content was low in both farming systems. This was attributed to acidity of the soils. However, the study concluded that CA has influence on soil nutrient content. The difference in nutrient content though not significant can be attributed to the farming systems since others factors such soil type, slope angle, climate, crops cultivated were similar in both plots. There was evidence of lack of application of fertilizers particularly in the plot under CA as well as poor management of crop residue in the plot under CF which somehow affected the performance of conservation agriculture. Poor management of crop residue poses questions on the animal husbandry practices among smallholder subsistence in the country as crop residue is usually used as fodder during winter.

The study noted a significant potential for the adoption of CA in Swaziland. However, the uptake of CA among the local subsistence farmers would improve if its introduction is built on reinforcing CA techniques familiar to the farmers such as minimum tillage, intercropping, crop rotation to name but a few. This implies that activities aimed at raising awareness and knowledge about CA must concentrate more on techniques less familiar to the farmers such as zero tillage and retention of crop residue. The promotion of cultivation of traditional crops, as a medium for introduction of CA, succeeded mainly because most of the farmers were already cultivating such crops as established in chapter 3 above. The overall findings of the study reveal positive outcomes of adoption and practice of CA. The study recognised the potential of CA to reduce cultivation costs and improve crop yields which is crucial to the local subsistence farmers if they have adopted and practiced the system correctly. The absence of baseline information about farming among the local subsistence farmers was a big challenge to the study. This affected almost all the components of the study. Nevertheless, the study was able to generate empirical evidence on the contribution of CA to address some of the immediate concerns of the farmers pertaining to crop cultivation. The practice of zero tillage and retention of crop residue protect the soil from degradation while conserving soil moisture and organic matter that is crucial for improvement and maintenance of soil fertility.

Adoption of CA by commercial farmers remains a challenge in Swaziland despite the fact that in Latin American countries and South Africa the system practiced by large-scale commercial farmers. The large-scale commercial farmers adopted CA mainly to reduce production costs and increase the profitability of their production. Production costs and productivity of agriculture is of immediate concern even to smallholder subsistence farmers. In most cases, innovation in agriculture is led by large-scale commercial farmers and smallholder farmers normally emulate farming techniques practiced by commercial farmers. Undoubtedly, the smallholder subsistence realizes the benefits of new agricultural innovation and show interest in its adoption it is practiced on a wide scale by commercial farmers. The leadership of commercial farmers in the uptake of CA techniques in the country is missing yet it is crucial as observed above. It is therefore recommended that the local large-scale commercial farmers be encouraged through policy and other means to adopt and practice CA.

7.3 RECOMMENDATIONS

From the forgoing research, it is evident that it is important for the country to improve the prospects of adoption of CA by subsistence farmers. Fundamentally, this may be done by addressing the various challenges presented above. Moreover, there is also a need of clear policy articulations on CA accompanied by vivid government commitment of resources into the process of introduction of the farming systems among the subsistence farmers. Currently, the introduction is through the support of the FAO, COSPE as well as other agencies and NGOs. Moreover, the policy pronunciations have to be backed by reforms in the national agricultural curriculum to include CA. Conservation agriculture must be taught in local schools and institutions of higher learning which train local farmers, extension officers and researchers.

Proper selection of crops has a number of benefits to farmers. One of them is the potential to increase the cropping frequency in dry land areas like the Lowveld and the Lubombo Plateau regions in Swaziland. Therefore it is important that proper technology, institutions and facilities are created to guide farmers in the selection of crops. Resources need to be invested in agricultural research to yield innovative strategies and scientific crop selection frameworks that would recognise traditional knowledge systems in existence. Moreover, the study views crop selection as an adaptation strategy to impacts of climate change. It is therefore imperative that the country shapes its agricultural policy such that it encourages farmers to select crops appropriate for prevailing and future climate patterns. Though farmers will always change crops in response to changes in climate but they need a critical and reliable information base. Agricultural research institutions need to include crop selection in their studies and information dissemination to farmers. This is to allow farmers to change to new crops rather than cling on cultivation of crops that have failed in the past. It is important also to study crop diversity in the country and how such can be conserved especially traditional crops.

The list of crops farmers wished to cultivate (Table 3.2) and the constraining factors they mentioned in Figure 4.5 may be interpreted as pointers towards desire by farmers to venture into cash crop farming. The government therefore needs to make adequate farming land and capital available as a fundamental major step towards addressing the problem of food shortage in the country and development of commercial farmers on communal areas. Moreover, the farmers with adequate land and supposedly capital for farming complained about lack of strength (due to ill-health) to cultivate crops. This, therefore, points to the significance of grooming the youth within the homesteads to take over farming in case the elders experience ill-health due to the rampant diseases affecting the local population.

This study is a precursor of major research activity that needs to be undertaken on CA in Swaziland. A long-term research programme is required in all areas where testing and validation units (TaVUs) exist in the country. The TaVUs are stations where all conditions necessary to practice CA were provided hence they are ideal to be base stations for long term research on the system. Literature on the systems, especially reporting on the practice of the system local is crucial. This is particularly so when accompanied by initiatives to introduce the system in the mainstream curriculum for agriculture in the country's education system from primary school to tertiary. Otherwise, the study, in a way, has indicated the potential of the system to improve soil nutrient content over time provided the system is practiced correctly by the local farmers.

Conservation agriculture has the potential to assist in safeguarding the food security situation within Swaziland, especially within the SNL. For this to happen it is essential that detailed record keeping and the large-scale dissemination of relevant knowledge is facilitated.

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8. APPENDICES

APPENDIX A

QUESTIONNAIRE ADMINISTERED TO CROP FARMERS AT SHEWULA IN THE STUDY OF CROPPING PATTERN AND CROP SELECTION CRITERIA

Sawubona! I am ……………………studying at UKZN. I have visited your homestead to conduct this interview with you pertaining to the selection and cultivation of crops in your homestead. As a respondent you will be treated with strictest confidentiality in case you feel unsafe owing to fear of reprisals due to what you might say**.**

Instructions

This questionnaire is to be administered by the researcher on a face-to-face interview with the respondent. All answers will be recorded in the spaces provided. Additional data will be recorded in a separate sheet. The respondents, as much as possible, must be heads of homesteads whether male or female. If head of homestead is not available the researcher will pass that homestead to another and make an appointment to come at a later time or date.

Sample No. (In place of name): ____________________ Gender: _________________

Age (range in cohort): ___________________________________

1. Type farming practiced.
   Conventional farming or conservation agriculture

2. Types of crops grown in the homestead, scale and combinations.

Types of crops	**Single/Combined**	**Scale (est.)**
_________________	______________	__________________
_________________	______________	__________________
_________________	______________	__________________
_________________	______________	__________________
_________________	______________	__________________
_________________	______________	__________________
_________________	______________	__________________

3. How you acquire the seeds for the crops grown?
   From other farmers
   From the shops
   From donated food
   From previous crop
   From relief agencies
   Other sources

4. Reasons for the growing of the crops presented above

Type of crops	**Reasons for cultivation**
________________________	____________________________________
________________________	____________________________________
________________________	____________________________________

5. Which crops are grown for consumption and for sale?

Names of crops	Consumption	For sale	Both

6. Who decides which crops to be grown in the homestead?

____

7. Are there crops associated with gender or age groups in their cultivation?

____

8. If ***"yes"*** provide the breakdown as follows:

Types of crops	Gender associated	Age-group associated

9. State the crops grown for the following properties or criteria

Properties	Name of crops
▪ Early maturity	
▪ Drought resistant/tolerant	
▪ High yields	
▪ Weed resistant/tolerant	
▪ Pest resistant/tolerant	
▪ Medicinal purpose	
▪ Other	

10. For crops grown for medicinal purposes, state the diseases the crops tackle.

Names of crops	Diseases they tackle

11. Which crops would you like to grow (not currently growing) and what are the constraints?

Names of crops	**Constraining factors**
____________________	____
____________________	____
____________________	____
____________________	____
____________________	____
____________________	____

12. How would you describe the yielding capacity of the various crops grown?

13. Is the crops' yielding capacity satisfactory to you?

14. Do you grow your crops for:
    Consumption only ______________________
    For sale only ______________________
    Both ______________________
    Do not farm ______________________

15. Estimate the amount of land dedicated to the cultivation of crops mentioned in (2). (*The research assistant will assist in the estimation of sizes)*.

Ngiyabonga (Thank you)!!!

APPENDIX B

QUESTIONNAIRE TO BE ADMINISTERED TO SHEWULA FARMERS PRACTISING CONSERVATION AGRICULTURE

The purpose of the questionnaire is to solicit information from farmers at Shewula pertaining to farming activities. The information required includes characteristics of farmers; their perceptions of conservation agriculture; the types of crops they are growing; as well as management crop residue in their cultivation areas. The respondents are implored to help answer the questions posed to them carefully and correctly. The information shall be used by the research only for academic purposes and will always be treated with confidentiality.

1. Demographic Details of the Farmers

1.1 Gender ____________________________

1.2 Age
- ☐ 20 – 29
- ☐ 30 – 39
- ☐ 40 – 49
- ☐ 50 – 59
- ☐ 60 and above

1.3 Education level
- ☐ None
- ☐ Primary School
- ☐ Secondary
- ☐ High school
- ☐Tertiary

1.4 Size of family (number of people in homestead) ____________________________

2. Perceptions of Conservation Agriculture

2.1 In which year did you start practicing conservation agriculture? __________________
____

2.2 What or who influenced you to adopt conservation agriculture? __________________
____
____

2.3 Is your entire farmland under conservation agriculture? __________________________
____

2.4 If 'no', what proportion of your farmland is under conservation agriculture? ________
____
____

2.5 Why have you adopted conservation agriculture partially? ________________________
____
____

2.6 Give your reasons for adopting conservation agriculture? ________________________
____
____

2.7 What are the (perceived) advantages of conservation agriculture? ________________
____
____

2.8 What are the problems (perceived) of conservation agriculture? _________________
____
____

2.9 What are the perceived advantages of conventional agriculture? _________________
____
____

2.10 What are the perceived problems of conventional agriculture? _________________
____
____

2.11 Do you feel more farmers will adopt conservation agriculture at Shewula? ________
____

2.12 If 'yes', why do you think so? ____
____

2.13 If 'no' why do you think so? ____
____

2.14 How would you rate your level of satisfaction with conservation agriculture (in a scale of ten)? ____
____

3. Growing of Crops and Crop Selection Criteria

3.1 State the types of crops you grow annually.
Under conservation agriculture: ____
____
____
Under conventional agriculture: ____
____
____

3.2 From the list (3.1) indicate the crops you grow alone or those that you mix. ________
____
____

3.3 Do you plant the same crop every year or change your crops every year? __________
____

3.4 If you change your crops why do you do that? _______________________________
____
____
____

3.5 If not, what constrains you from changing your crops? ___________________________
____
____

3.6 From the crops you grow, do you use indigenous seed or hybrid seed? _____________
____

3.7 Please explain the reasons for your choice of seed. _______________________________
____
____
____

3.8 Where do you acquire the seed? ____
____
____

3.9 Have you noticed any decline or increase in your yields? _________________________
____

3.10 Give the reasons for the decline or increase in your yields. ______________________
____
____
____

3.11. Is the yield adequate to provide for your household's food needs? _______________
____

3.12 If 'yes', do you have any surplus? ____
____

3.13 If 'no', how do you make up for shortfall? _____________________________________
____
____

3.14 What is the use or importance of the crops mentioned in 3.1? ___________________
____
____
____

3.15 Do you apply artificial fertilizer when cultivating your crops? ___________________
____

3.16 Do you use chemicals to control diseases and weeds in your cropland? ____________
____

3.17 Is the rainfall received in the last five years adequate for farming? _______________
____

3.18 If 'no', how did you manage to grow your crops? ______________________________
____
____
____

3.19 Do you practice fallowing? ____
____
____
____

3.20 If yes, state why you practice fallowing. ___________________________________
____
____
____

3.21 If no, what are the constraints? ____
____
____
____

3.22 Who selects the crop to be grown in the homestead? _________________________
____

3.23 What factors does she or he consider in the selection of crops to be grown? _______
____
____
____

4. **Management of Agricultural Land and Crop Residue**

4.1 Has the fertility of your soil improved or declined since you started practicing conservation agriculture? ____
____

4.2 Give reasons for the decline or improvement in your soil fertility. _______________
____
____
____

4.3 How do you maintain or improve the fertility of the soil in the fields under conservation agriculture? ____
____
____

4.4 During the ploughing season, what do you do with the crop residue on your cultivation land? ____
____
____

4.5 How do you control soil erosion in your conservation agriculture fields? __________
____
____

4.6 Do you perceive a problem of soil erosion in your cultivation area? _______________
____

4.7 If 'yes', how have you noticed it? ____
____

4.8 State any soil erosion control practice (s) in your cultivation area. ________________
____
____

4.9 Who advised you on the soil conservation practices you are implementing? ________
____

4.10 Why is it important to conserve soil from erosion? ___________________________
____
____
____

4.11 What types of implements do you use in your conservation agriculture fields? _____
____
____

4.12 Are there any problems you experience in the acquisition and accessing the implements?
____

4.13 If 'yes', state the nature of problems you experience. __________________________
____
____

4.14 Explain how you solve the problems. _______________________________________
____
____

4.15 What is/are the main problems (s) associated with livestock grazing on cultivation areas?
____
____
____

4.16 Would you agree to the notion of banning of livestock grazing in cultivation areas in winter? ____
____

4.17 If you disagree give reasons why you disagree. _____________________________
____
____

4.18 If you agree explain how livestock grazing in winter will be approached. _________
____
____
____

4.19 What are the advantages of tilling the soil before planting crops? _______________
____
____

4.20. What are the advantages of planting crops without tilling the soil? ______________
____
____
____

4.21 What are the disadvantages of planting crops without tilling the soil? _____________
____
____

4.22 How do you balance conservation agriculture with livestock farming especially with respect to winter grazing on farmlands? ____
____
____

4.23 What is your opinion on the notion that conservation agriculture is more labour intensive than conventional farming? ____
____
____

5. Socio – Economic Issues

5.1 What are the main sources of livelihood in the homestead i.e. sources of food and income?
____

5.2 How many family members participate actively in farming activity in the homestead?
____

5.3 Are these people adequate to satisfy the labour requirement of the farming activity? __
____

5.4 If 'not', how do you augment the family labour? _______________________________
____

5.5 How do you or did you acquire or access farm implements? _____________________
____

5.6 State the crop storage facilities you have? ___________________________________
____

5.7 Have you ever accessed credit for farming? ___________________________________
5.8 If 'yes', where did you acquire the credit? ___________________________________
____

5.9 If 'no', what disqualified you? ____
____

5.10 Do you market any of crops? ____

5.11 If 'yes', which crop do you market? _______________________________________

5.12 Is the market available for the crop marketed? _______________________________

5.13 What are your dreams or future plans on farming? ___________________________
____

6. Institutional Support

6.1 What support do you receive from government pertaining to farming? _____________
____

6.2 Do you receive any funding from government or any organization? _______________

6.3 What services do you receive from government i.e. traction; fertilizers; pesticides; seeds etc.
____

6.4 Are these services free or pay for them? _____________________________________
____

6.5 If you pay for them, are you able to afford them? ______________________________

6.6 Are these services adequate in terms of their availability at the time you need them? _
____

6.7. In case you do not afford them or they are inadequate, what do you do then especially the availability of tractors? ____
____
____

6.8 What is government doing to support the adoption and practice of conservation agriculture at Shewula? ____
____
____

6.9 What is the role of government agricultural extension officers? __________________
____
____

6.10 How frequent do the extension officers visit your homestead? __________________
____
____

6.11 What is the policy on the grazing of livestock at Shewula? _____________________
____
____

6.12 State the procedure followed if one intends to prohibit the grazing of livestock in the farmland during winter. ____
____
____

6.13 Are there any threats of eviction that stop you from investing on improvements on your land? ____
____
____

6.14 If 'yes', state the nature of the threats. _____________________________________

Ngiyabonga !!!

APPENDIX C

QUESTIONNAIRE TO BE ADMINISTERED TO SHEWULA FARMERS PRACTISING CONVENTIONAL AGRICULTURE

The purpose of the questionnaire is to solicit information from farmers at Shewula pertaining to farming activities. The information required includes characteristics of farmers; their perceptions of conservation agriculture; the types of crops they are growing; as well as management crop residue in their cultivation areas. The respondents are implored to help answer the questions posed to them carefully and correctly. The information shall be used by the research only for academic purposes and will always be treated with confidentiality.

---

1. Demographic Details of the Farmers

Respondent's No. ____________________

1.1 Location of homestead (GPS) ____________________________

1.2 Gender ____________________________

1.3 Age
- ☐ 20 – 29
- ☐ 30 – 39
- ☐ 40 – 49
- ☐ 50 – 59
- ☐ 60 and above

1.4 Education level
- ☐ None
- ☐ Primary School
- ☐ Secondary
- ☐ High school
- ☐ Tertiary

1.5 Size of family (number of people in homestead) ____________________________

2. Perceptions of Conservation Agriculture

2.1 Have you heard about conservation agriculture? ____________________________

2.2 If yes, describe its key features as you have been informed. ______________________
____
____
____

2.3 Why have you not started practising CA? ____________________________________
____
____

2.4 Do you feel that at some point you'll adopt and practise CA? ____________________
____

2.5 If 'yes', what will be the motivating factors or reasons? ________________________
____
____
____
____

2.6 If 'no', give reasons for your reluctance to adopt and practice CA. ________________
____
____
____

3. Growing of Crops and Crop Selection Criteria

3.1. State the types of crops you grow annually. _________________________________
____
____

3.2 From the list (3.1) indicate the crops you grow alone or those that you mix._________
____
____
____

3.3 Do you plant the same crop every year or change your crops every year? ___________
____

3.4 If you change your crops why do you do that? _______________________________
____
____

3.5 If not, what constrains you from changing your crops? _________________________
____
____

3.6 From the crops you grow, do you use indigenous seed or hybrid seed? _____________
____

3.7 Please explain the reasons for your choice of seed. ____________________________
____
____
____

3.8 Where do you acquire the seed? ____
____
____
____

3.9 Have you ever cultivated seed sourced from overseas? _________________________

3.10 Has the extension officer advised you or taught you on GMOs? ________________

3.11 Have you noticed any decline or increase in your yields (*question not related to GMOs)*?
____

3.12 Give the reasons for the decline or increase in your yields. ______________________

3.13 Is the yield adequate to provide for your household's food needs? ________________

3.14 If 'yes', do you have any surplus? ____

3.15 If not, how do you make up for shortfall? _____________________________________

3.16 Is the rainfall received in the last five years adequate for farming? _______________

3.17 If no, how did you manage to grow your crops? ________________________________

3.18 Do you practice fallowing? ____

3.19 If yes, state why you practice fallowing. ______________________________________

3.20 If no, what are the constraints? ____

3.21 Who selects the crop to be grown in the homestead? ___________________________

3.22 What factors does she or he consider in the selection of crops to be grown? ________

4. **Management of Agricultural Land and Crop Residue**

4.1 Has the fertility of your soil improved or declined in the last five years? ____________

4.2 Give reasons for the decline or improvement in your soil fertility. _________________

4.3 How do you maintain or improve the fertility of your soil? ______________________
____
____

4.4 During the ploughing season, what do you do with the crop residue on your cultivation land? ____
____
____

4.5 Is there a drainage facility in your cultivation land for management of rainwater? ____
____
_

4.6 Do you perceive a problem of soil erosion in your cultivation area? _______________
____
_

4.7 If yes, how have you noticed it? ____
____
____

4.8 State any soil erosion control practice (s) in your cultivation area. ________________
____
____

4.9 Who advised you on the soil conservation practices you are implementing? _________
____

4.10 Why is it important to conserve soil from erosion? ____________________________
____
____

4.11 What do you use for ploughing your fields? _________________________________
____

4.12 Are there any problems you experience with what you use for ploughing? _________
____
_

4.13 If yes, state the nature of problems you experience. ___________________________
____
____

4.14 Explain how you solve the problems. _______________________________________
____
____

4.15 What is/are the main problems (s) associated with livestock grazing on cultivation areas?
____
____

4.16 Would you agree to the notion of banning of livestock grazing in cultivation areas in winter? ____
____

4.17 If you disagree give reasons why you disagree. ______________________________

4.18 If you agree explain how livestock grazing in winter will be approached. __________

4.19 Will you consider planting crops without tilling the soil? ______________________

4.20 What are the advantages of tilling the soil before planting crops? _______________

4.21 What are the disadvantages of planting crops without tilling the soil? ____________

5. Socio – Economic Issues

5.1 What are the main sources of livelihood in the homestead i.e. sources of food and income?

5.2 How many family members participate actively in farming activity in the homestead?

5.3 Are these people adequate to satisfy the labour requirement of the farming activity? __

5.4 If 'not', how do you augment the family labour? ______________________________

5.5 How do you or did you acquire or access farm implements? ____________________

5.6 State the crop storage facilities you have? __________________________________

5.7 Have you ever accessed credit for farming? _________________________________

5.8 If 'yes', where did you acquire the credit? __________________________________

5.9 If 'no', what disqualified you? ____

5.10 Do you market any of crops? ____

5.11 If 'yes', which crop do you market? ____
____

5.12 Is the market available for the crop marketed? _________________________________

5.13 What are your dreams or future plans on farming? ______________________________
____
____

6. Institutional Support

6.1 What support do you receive from government pertaining to farming? _____________
____

6.2 Do you receive any funding from government or any organization? _______________

6.3 What services do you receive from government i.e. traction; fertilizers; pesticides; seeds etc.
____

6.4 Are these services free or pay for them? ______________________________________
____

6.5 If you pay for them, are you able to afford them? _______________________________
____

6.6 Are these services adequate in terms of their availability at the time you need them? __
____

6.7. In case you do not afford them or they are inadequate, what do you do then especially the availability of tractors? ____
____
____

6.8 What is government doing to support agriculture at Shewula? ____________________
____
____
____

6.9 What is the role of government agricultural extension officers? __________________
____
____

6.10 How frequent do the extension officers visit your homestead? __________________
____
____

6.11 What is the policy on the grazing of livestock at Shewula? _____________________
____
____

6.12 State the procedure followed if one intends to prohibit the grazing of livestock in the farmland during winter. ____

____

____

6.13 Are there any threats of eviction that stop you from investing on improvements on your land? ____

____

____

6.14 If 'yes', state the nature of the threats. ____

____

____

Ngiyabonga kakhulu (Thank you very much)

APPENDIX D

AGENDA FOR FOCUS GROUP DISCUSSIONS

AGENDA FOR CONSERVATION AGRICULTURE (CA) FGD

1. Introduction: The included participants' stating their names and surnames as well as the farming systems they are practicing *i.e.* conservation agriculture or conventional farming.
2. Reasons or factor for adoption of CA.
3. Five key principles of CA.
4. Discussions of advantages of CA over conventional farming (CF) techniques.
5. Discussions of advantages of CF over CA.
6. Perceived disadvantages of CA.
7. Perceived disadvantages of CF.
8. List the CA techniques currently being practiced.
9. Description of how they actually practice CA.
10. Amount of land farmers dedicated to CA and reasons for the stated amount.
11. Sources of seed.

AGENDA FOR CONVENTIONAL FARMING (CF) FGD

1. Introduction: The included participants' stating their names and surnames as well as the farming systems they are practicing *i.e.* conservation agriculture or conventional farming.
2. Reasons or factor for not adoption of CA.
3. Five key principles of CA known to the farmers.
4. Discussions of perceived advantages of CA over conventional farming (CF) techniques.
5. Discussion of perceived advantages of CF over CA.
6. Perceived disadvantages of CA.
7. Perceived disadvantages of CF.
8. List the CA techniques currently being practiced.
9. Factors that may motivate the farmers to adopt CA.
10. Amount of land farmers they will dedicate to CA and reasons for the stated amount.
11. Sources of seed.

APPENDIX E

COMPUTATION AND INTERPRETATION OF THE STUDENT'S *T*-TEST

The study relied on the student's *t*-test in the analysis of the results of the study to ascertain the significance of difference in the values of parameters measured in soils under conservation agriculture (CA) and those under conventional farming (CF) techniques. Two data sets for soil moisture content are used from the sampling site TaVU 1. The step-by-step computation of the *t*-test for independent samples was done as follows:

TaVU 1 data set

Working with sample values of two independent variables x and y, first was the calculation of the mean and establishment of the deviations from the sample mean:

$x - \bar{x}$ and $y - \bar{y}$ and the square mean deviations $(x - \bar{x})^2$ and $(y - \bar{y})^2$

The data for variable x and y and the resulting working table is shown in table 6.1. You should note that both n_x and n_y are 6 which means $n_{x} = n_{y}$.

The researcher kept in mind that before the *t*-test can be applied, two assumptions must be made. These are:

i. The background populations of the samples are approximately normally distributed. This is especially the case where there is a small samples as it is the case with this study
ii. The standard deviations of the populations from which the samples are drawn are equal.

Working table for calculation of *t*-test

TaVU 1 CA % moisture (x)	TaVU 1 CF % moisture (y)	$x - \bar{x}$	$y - \bar{y}$	$(x - \bar{x})^2$	$(y - \bar{y})^2$
6.9	5.6	-0.7	0.89	0.49	0.7921
10.2	3.4	2.6	-1.31	6.76	1.7161
6.1	4.2	-1.5	-0.51	2.25	0.2601
5.8	6.3	-1.8	1.59	3.24	2.5281
10.8	5.8	3.2	1.09	10.24	1.1881
4.6	4.0	-3.0	-0.71	9.00	0.5041
6.8	3.4	-0.8	-1.31	0.64	1.7161
8.4	4.2	0.8	-0.51	0.64	0.2601
9.0	4.8	1.4	0.09	1.96	3.8416
7.4	5.4	-0.2	0.69	0.04	0.0016
76.0	**47.1**			$\sum(x - \bar{x})^2 =$ **35.26**	$\sum(y - \bar{y})^2 =$ **12.808**
$\bar{x} = 7.6$	$\bar{y} = 4.71$				

To ascertain the significance of difference between the soil moisture values in the CA and CF plots in site TaVU 1 the approach of hypothesis testing was used as follows:

i. State the null hypothesis (H_0): There is a difference in the soil moisture content between the plot under CA and the plot under CF.

ii. State the alternative hypothesis (H_1): There is no difference in the soil moisture content between the plot under CA and the plot under CF.

iii. Rejection or acceptance level (α) is set at *0.05*

iv. Then done the test by following the sub-steps:

a) Calculation of the standard deviations of the populations. The standard deviations (σ) of the populations were obtained from all the data in both samples using the following equation:

$$\sigma = \frac{\sqrt{\sum(x-\bar{x})^2 + (y-\bar{y})^2}}{n_x+n_y-2}$$

$$= \sqrt{\frac{35.26 + 12.808}{10+10-2}}$$

$$= \sqrt{\frac{48.068}{10}}$$

$$= \sqrt{4.8068}$$

$$= 2.1924$$

b) Then calculation of the standard deviations of the sampling distribution of x and y (*i.e.* the standard errors of sample means). The following formula was used:

$$\text{S.E.}_{\bar{x}} = \frac{\sigma}{\sqrt{N_x}} = \frac{2.192}{\sqrt{10}} = \frac{2.192}{3.162} = 0.693$$

$$\text{S.E.}_{\bar{y}} = \frac{\sigma}{\sqrt{N_y}} = \frac{2.192}{\sqrt{10}} = \frac{2.192}{3.162} = 0.693$$

c) Then the calculation of the standard deviations of the sampling distribution of the difference between means, that is, the standard error of $\bar{x} - \bar{y}$. This was obtained by using the formula:

$$\text{S.E.}_{\bar{x}-\bar{y}} = \sqrt{(\text{S.E.}_{\bar{x}})^2 + (\text{S.E.}_{\bar{y}})^2}$$

$$= \sqrt{(0.693)^2 + (0.693)^2}$$

$$= \sqrt{0.480 + 0.480}$$

$$= \sqrt{0.960}$$

$$\mathbf{= 0.98}$$

d) The calculation of t was done by using the formula:

$$t = \frac{\text{the difference between the means}}{\text{the standard error of the difference}}$$

Therefore,

$$t = \frac{\bar{x} - \bar{y}}{\text{S.E.}_{\bar{x}-\bar{y}}}$$

$$= \frac{7.6 - 4.71}{0.98}$$

$$= \frac{2.89}{0.98}$$

$$= \underline{\mathbf{2.95}}$$

e) Now, to decide whether to reject or accept H_0 based on the results obtained, the researcher kept in mind that:

i. The rejection level was set at *0.05*. Check the student's *t*- test distribution under column heading *0.05*

ii. Establish the degrees of freedom $(n_x + n_y - 2)$ = 10 + 10 – 2 = 18

iii. Under column *0.05* with 18 degrees of freedom the critical value of 2.10 was obtained

iv. For the difference between sample means $(\bar{x} - \bar{y})$ to be significant, *t* must be more than 2.10.

The researcher noted the fact that there were two-tailed critical values of *t* as indicated on the table of student's t-test distribution. This is appropriate for this example because H_1 was non-directional. If H_1 had been directional, the critical value of *t* would have been found under the *0.10* column heading, since a two-tailed probability of *0.10* column is equal to a one-tailed probability of *0.05*. The critical value would then have been 1.73.

v. For H_0 to be rejected by the researcher, the calculated *t*-value must be more than the critical value. In this case *t* was calculated to be 2.95 and the critical value was found to be 2.10. Therefore, H_0 is rejected as the calculated *t*-value is greater than the critical value.

vi. Therefore, the researcher concluded that there was no significant difference in the soil moisture content between the plot under CA and the plot under CF.