Soil and Water Conservation Farming Practices, in the Communal Areas of the Central Eastern Cape Province, South Africa.

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January 2004

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Together in Excellence

A thesis submitted in fulfilment of the requirement for the degree of Master of Agriculture, in the Faculty of Agricultural and Environmental Sciences, at the University of Fort Hare.

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January 2004

CERTIFICATION

We certify that the work reported in this thesis was carried out by Maudline Mabi (nee Ngqolwazana) under our supervision.

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Prof. T.E. Simalenga	Mr. A. B.D. Joubert

On this………day of………2004

DEDICATION

Dedicated to my eldest daughter, Andiswa who experienced so many dreadful difficulties when I was doing this study.

ACKNOWLEDGEMENTS

I wish to acknowledge the following people for their contribution to the successful completion of the study:

I am very greatful to my supervisors, Prof. T.E. Simalenga, Mr ABD Joubert and the late Mr. O.T. Mandiringana for their excellent contribution to my study; their keen guidance is greatly appreciated.

I am also very grateful to Mr. A. B. D. Joubert for his parenthood and contribution provided to me.

My appreciation is also extended to my loving children for enduring my long absence from home and for their encouragement and forbearance. Thank you to my sister Noxolo for her support throughout and to my late brother in-law, Mr. P. G. Kom, and his wife, Nonezile, for their patience and help when my house/family were above and beyond the call of kinship.

Also acknowledged is the excellent support provided by my colleagues Mr. L. N. Mdledle, Ms. P.P.W. Peter, the late Mr. L. Mabusela for their assistance throughout. I have also benefited from other students and colleagues concerning computers. In particular thanks to Mr. L. Qongqo. Special thanks also go to the extension officers and the farmers in all the districts I worked in.

Funding received from the ARDP and the Canon Collins education trust is particularly acknowledged.

ABSTRACT

A survey was carried out to investigate the extent of use of conservation tillage practices for soil and water management under smallholder farming conditions in the central region of the Eastern Cape Province. The survey was carried out in five districts viz: Middledrift, Sada, Keiskamahoek, Zwelitsha and Seymour. Participatory Rural Appraisal (PRA) was conducted whereby village meetings were held in each area, then a total of 45 rural households were identified by local extension officers for participation in in-depth interviews.

Detailed information on socio-economic issues, labour and farm power availability, land management issues, conservation farming practices in use, cropping systems and yields were recorded using informal interview techniques and a semi-structured questionnaire which was designed for this purpose.

The study has shown that more than 80% of smallholder farmers in the study area own and use draught animals as the main source of farm power. The average of the arable land is 2ha per each farmer. Twenty percent of farmers hire tractors for opening new land and during winter fallowing.

A total of nine conservation farming practices were identified, including earth contour bunds practised by 82% of all farmers interviewed; manuring (82%); crop rotation (77%) and grass mulching (25%). Other practices

identified were the use of vegetative barriers, stone bunding and open furrow ridging which is used for drainage purposes.

On-farm trials were conducted with farmers to assess the performance of conservation tillage using the animal drawn ripper (minimum tillage trial), pot-holing and the use of tied-ridging techniques. The results showed that tie-ridging and pot-holing were good in conserving water. They also showed better grain and stover yield. The farmers indicated that the ripper plough was the most suitable to them as it saves both time and labour.

The study concludes that the promotion of conservation tillage systems that enhance soil fertility and water use efficiency, improve peak labour constraint and sustain the environment should be given due consideration and high priority for the improvement of agricultural productivity of small-holder farmers especially in the low rainfall areas.

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CHAPTER 1
INTRODUCTION

Conservation farming, which some people refer to as conservation tillage or minimum tillage, is defined as the application of farming practices which aim to minimise tillage operations, reduce overall energy requirements and conserve resources at the farm level. These practices can range from conserving water/moisture so as to sustain the crops through dry weather spells to conservation of soil fertility and minimising of labour and other direct farm inputs in order to improve productivity of the farm.

Most areas of the Eastern Cape Province receive low and erratic rainfall and the majority of its people live in rural areas (Kepe, 1992). Production of summer crops is usually risky as a result of this low and erratic rainfall combined with the hot dry spells, which are a normal part of the weather pattern during the most important months of the crop's development. Despite the harsh weather conditions most farmers in the region, especially those in communal areas, still endeavour to produce food crops under dryland conditions. Yields are usually very low and mostly are subsistence levels. On the whole, South Africa is a dry country, with average annual rainfall highest in the east and progressively lower towards the west. Less than 65 per cent of the land receives the minimum of 500-mm rainfall (van Wontergham,1998).

The Republic of South Africa covers an area of 1,219,090 sq km, of which only 14% is arable and is divided into 9 provinces as shown in Fig. 1, with approximately 40 million people. The central region of Eastern Cape province is one of South Africa's former black homelands ((Kepe, 1992).

It is generally acknowledged that one way to improve dryland crop production in the arid and semi-arid regions is to retain all rainfall received by techniques that reduce surface runoff, improve infiltration and increase the water storage capacity of the soil (FAO, 2000). Such techniques have long been used traditionally in various countries in Africa for example, the *trus* system (U-shaped earth bunds) in the Sudan, the *zai* system (planting pits dug out with traditional hoes) in Mali and Burkina Faso, and the *tassa* system (planting pits) in Niger (Reij *et al.*, 1996). Other systems of soil and water conservation that have been widely tested and used on the continent include tied ridges (Nyagumbo, 1999; Kayombo *et al.*, 1999), clean ripping and mulch ripping (Chuma and Hagmann, 1997; Nyagumbo, 1999); hillside terraces or stone bunds (Reij *et al.*, 1996; Kayombo *et al.*, 1999), micro-basins (Reij *et al.*, 1996) and trash-lines (Reij *et al.*, 1996; Kayombo *et al.*, 1999).

Conventional farming is always associated with intensive tillage and cultivation practices that overly manipulate the soil, leaving it bare and unreceptive to water entry, as well as creating a plough pan (Makaya, 1993). This often leads to severe water and wind erosion, organic matter and nutrient loses with consequent reductions in productivity.

Therefore the major objective of the study was to conduct a survey to determine the extent on the use of soil and water conservation and conduct on farm trials on selected conservation tillage technologies which have been tried in other countries and have a potential of being adopted in the Eastern Cape Province..

The specific objectives were as follows:

1. Conduct a baseline survey and document commonly or locally practised conservation farming methods.
2. Conduct on farm trials to evaluate the following technologies available for conservation farming: tie ridging, pot holing and ripping.
3. To recommend conservation farming technologies with a potential for wider adoption, and
4. To assess farmers' response and their evaluation of the system for the possibility of adoption and use.

CHAPTER 2
LITERATURE REVIEW

Agriculture plays a crucial role in the growth and development of the country. The contribution of agriculture to livelihoods in Eastern Cape Region decreased steadily from about 51% in the 1950's down to about 20% in 1984 and 8.1% or less at present (Antrobus *et.al.* 1984). The main constraint to agricultural production in the region is the loss of soil and fertility degradation because of erosion and abusive exploitation using non appropriate cropping techniques (Laker, 1978).

Conservation tillage is aimed at reducing soil disturbance which in turn can minimise soil erosion and preserve soil moisture. In less developed countries most of those involved in agriculture are faced with poverty due to lack of insufficient rainfall and land degradation because of erosion. As stated by Oldreive (1993), drought or insufficient rainfall is one of the major causes of crop failure and, thus, one of the causes of poverty among small-scale farmers. It is critical that what rainfall is received is captured and used to maximum effect.

Considerable research and development work on conservation tillage techniques has been conducted in South Africa over the past 25 years, however, much of research effort has been directed towards large scale commercial farmers and as on-station experiments. Very little has been done to assist small-holder farmers who mainly use draft animals as their main source of farm power (Fowler, 1999; Heyns, 1987; Mallet, 1987). Similar observations have been reported in most East and Southern African countries where there has been very low adoption of conservation farming technologies among smallholder farmers (Kaumbutho, *et. al*, 1999).

According to Kaumbutho, *et.al* (1999), conservation tillage has been practised on large scale farms of the region for a while and is now receiving a new focus for smallholder agriculture, with a new re-awakening and interest in soil, water and general environmental preservation.

Smallholder agriculture in East and Southern Africa has special lessons to learn from the agricultural mechanisation endeavour, which is at different levels in different countries and which remains a major challenge for governments and farmers alike. [illegible] tractorisation programmes in the region have hardly served the power supply needs of smallholders, animal traction has proved itself as a dependable and versatile source of agricultural power for tillage and transport (Simalenga and Joubert, 1997a). Despite the poor image of draft animal power and the neglected support services, it has survived and is still widely used by smallholder farmers in the rural areas and communities of South Africa (Simalenga and Joubert, 1997a; Simalenga and Joubert, 1997b).

2.1 Conservation tillage system

Conservation farming, sometimes referred to as conservation tillage or minimum tillage, is usually defined as a farming practice which aims at conserving resources at the farm level. This can range from conserving water or moisture so as to sustain the crops through the dry weather spells to conserve the long term fertility of top soil, minimising labour and other farming inputs in order to improve productivity of the farm.

In conservation tillage, crops are grown with a minimal cultivation of the soil. When the amount of tillage is reduced, the stubble or plant residues are not completely incorporated, and most or all remain on top of the soil rather than being ploughed or disked into the soil. The new crop is planted into this stubble or small strips of tilled soil. Methods described as no-till, minimum till, incomplete tillage, reduced tillage, or conservation tillage differ from each other mainly in the degree to which the soil is disturbed prior to planting (Peet, 1997). Conservation tillage has now been defined in various ways which all capture the need for less soil manipulation, hence reduced energy requirement and capacity to leave crop residue on the soil surface during all tillage operations (primary or secondary). The common theme is one of reduced soil and water losses (Kaumbutho and Simalenga, 1999 (a). Other writers define conservation tillage as the system that leaves at least 30% of the soil covered by crop residues (Peet, 1997).

Peet (1997) also stated that in another variation of reduced tillage, narrow strips are tilled and then planted by standard equipment. Where soils are compacted but subject to erosion, strip tillage is a good compromise because crops can be planted efficiently and grow well in the loosened soil of the tilled strips while the untilled portions of the field conserve soil and water.

While soil and water conservation efforts in the region are not new, tillage for soil and water conservation has seen many shortcomings, ranging from professional redress to technological limitations and socio-economic bottlenecks. Conservation tillage has been practised for sometime on large scale farms of the region but is now receiving new focus for small holder agriculture, with a re-awakening of the interest in soil, water and general environmental preservation.

2.2 Conservation tillage and crop production

Crop production in the central Eastern Cape region can be sustained at a high level only on the irrigation schemes and in a few selected areas. In most parts of the study area crop production is limited due to very poor climatic conditions (low and erratic rainfall), topography (fields on shallow steep slopes), socio-economic factors (expensive operations for cropping, labour markets not available and unfavourable political factors and inadequate infrastructure (fences, irrigation schemes not available). Research at the University of Fort Hare has indicated that soils of the region require a minimum of 360 mm of rain (including water stored in the profile) to produce a crop of maize (Agricultural and Rural Development Research Institute (ARDRI), 1989). It was also reported by (ARDRI 1989) that top yields can usually be obtained with 700 mm water available to the crops when well distributed during the growing season.

Marais (1978) found out that apart from the limited quantity of rain (unreliability of the rainfall), its unfavourable distribution during the growing season also severely restricts the growth of summer crops in most areas of the Eastern Cape Province. Marais (1978) that the most limiting factor was the pronounced water deficit which generally occurs in January, a critical month in the maize production cycle. The unfortunate aspect of the annual rainfall in the central region of the Eastern Cape province is that a significant fraction of the rain is received too late to be of real benefit to summer crops. Moreover of the rain falls in brief high intensity storms resulting in heavy runoff. Approximately 20% of the showers are light and contribute little or nothing to soil moisture.

The most important elements of weather which influence crop performance are radiant energy and moisture (Mallet and de Jager, 1974). Water conservation (or storage in soil) is the net result of the interactions of a series of complex factors and processes. These include the amount, distribution, and type of precipitation; water infiltration, runoff, evaporation, distribution in the profile, and deep percolation; soil characteristics namely texture, depth, density, and organic matter content; and management practices used on the land including residue management, tillage systems, cropping system, and weed control.

Evaporation of moisture from soil can be reduced by improving the ground cover. Mulch and live vegetation shade the soil and thus reduce evaporation caused by direct sun. An often overlooked means of increasing the water available for agriculture is to reduce the loss of water through transpiration and evaporation. Minimising losses from evaporation is an effective way of increasing available water and as the amount of water loss through evaporation is very high. An average of 4 mm of water is evaporated per day from open water surfaces during the winter months and up to 10 mm per day during a hot summer (ARDRI 1989).

Leaving ground cover helps to reduce run-off and increases infiltration and percolation, as does leaving the soil undisturbed by practising zero or minimum tillage. The residues intercept raindrops, thus preventing the detachment of soil particles, which is the first step in the erosion process. With good moisture conservation practices Ciskeian soils may give modest yields of some crops (Hensley and Laker, 1978).

Consumptive use of water by maize peak in January and February. At this time maize is most sensitive to water stress and much of Eastern Cape maize flowers and forms its grain then. Rainfall distribution during the growing season is therefore very unfavourable for maize. Research conducted by Agricultural Rural Development Research Institute (ARDRI, 1997) indicated that inadequate water is by far the major limitation to maize production. It also shows that it is not a low rainfall per se which is a problem but rather a combination of the following factors:

(i) variability of rainfall between and within cropping seasons is very high;

(ii) much rain falls in brief high intensity storms resulting in heavy runoff; and

(iii) approximately 20% of the showers are light and contribute little or nothing to soil moisture.

Many of the Eastern Cape soils have very low water holding capacity being only approximately 500 mm deep. Such soils are not able to store enough water in the profile to cope with the midseason drought (ARDRI, 1997). The factors determining the potential of an area for crop production can be grouped into two main categories (Brutsch, 1984).

a) the biophysical potential of the available land, and

b) the socio-economic situation.

Brutsch (1984) went further on to say that Ciskei (central Eastern Cape) suffers from severe limitations in both respects. Various research, extension and development work has proven the value of conservation tillage, which was proved to have advantages for farmers in crop production. The advantages are, however, yet to become common knowledge to be translated into utilisable and widely adopted techniques (Kaumbutho *et al*., 1999).

2.3 Conservation tillage and land degradation

Land degradation is currently a major concern in South Africa and is one of the major problems facing agriculture today. With reference to the Northern Province, Burgers & Bruwer (1995) note that one third of the former homeland of Lebowa is severely degraded by erosion, while their comparative estimate for Venda is 20%. With regard to Venda, Bembridge (1988) highlighted evidence of considerable misuse and deterioration of natural resources, resulting in soil erosion, in keeping with the general continuum of conventional option. The issue of overgrazing and the need for reducing stock numbers in Venda was emphasised in a similar vein in Department of Water Affairs (DWAF, (1993a). When soil is bare because vegetation has been removed or when vegetation is not abundant, rainwater runs off with soil particles. Mismanagement of land is seen as the main cause of erosion.

Farmers are less aware that conventional farming systems are destroying the land upon which they depend. Most farmers notice the inexorable decline in the productivity of their fields, however, they generally believe this is a natural and irreversible process. The practise of turning the soil before planting is so universal that the plough has for centuries been a symbol of agriculture. When the land is treated in a holistic way, many of the symptoms of erosion can be eliminated (Vukasin *et al*, 1995).

As indicated by Trollope *et al*, (1[illegible]basic factor which causes land degradation is incorrect land use and also the use of the modern, or mouldboard, plough. In arable agriculture the most common error is cultivating lands that are too arid for crop farming. Trollope et al., (1986) further stated that even in the planned areas of the national and independent states in South Africa no efforts were made to draw up systems of land use based on the natural factors of the environment. Consequently areas were demarcated or retained for cultivation in regions that are completely unsuited for dry land crop farming.

Conservation tillage can be very effective in reducing soil erosion, depending on the amount of residue cover retained on the soil surface. One of the most effective remedies for land degradation is "conservation tillage"- a revolutionary cultivation techniques in which the fields are not ploughed. "This concept sprang directly from the recognition that mechanical ploughing is contributing to land degradation on a massive scale, particularly in tropical and sub-tropical countries," FAO Senior Agricultural Engineer Theodor Friedrich (Benites, Undated).

Vukasin *et al.* (1999) stated the ways to prevent erosion as the following:

- Use minimum tillage in order to leave the soil undisturbed.
- Cover the ground with living plants, plant residues or even stones.
- Add organic matter to the soil.
- Break the force of wind with trees, hedges and other plants, to reduce blowing away of the soil.
- Create bunds, swales or terraces along contours to slow the flow of water.

A further development has been the realisation that resource –poor farmers have perceptions of soil, erosion and conservation that can be crucial importance in understanding their attitudes and strategies (Harper & El-Swaify, 1988; Fujisaka & Garrity, 1991; Ostberg, 1991; Sikana, 1994; Kiome & Stocking, 1995). Kaumbutho, *et al* (1999), stated that the problem of soil water losses through surface runoff and evaporation is one of the major limiting factors in agricultural production today

Kaumbutho, *et al* (1999), stated that the problem of soil water losses through surface runoff and evaporation is one of the major limiting factors in agricultural production today.

Critchley & Netshikovhela (1998) stated that while traditional agricultural practices were not always derided by colonial agriculturists, it was more common (and less controversial) to condemn that the condone 'native practices'. With certain historical exceptions (eg Savonnet, 1958; Randall, 1963; Allan, 1965), the approach has been- and still is – to ignore examples of indigenous soil and water conservation or simple fail to recognise their presence or relevance. Makhaya stated that in Kangwane, poverty and overpopulation is associate with land degradation through erosion.

2.4 **Some available technologies for Conservation Tillage systems**

Conservation tillage has been acknowledged as a productive technology for crop production in the commercial farming sector. Commercial farmers in Namibia were reported to have started shifting towards conservation tillage practices over 15 years ago an[illegible]s have been well-appreciated (Maltzahn, 1998). Some farmers have not only benefited from the increased yield but also increased soil productivity.

Considerable work has taken place in many African countries on conservation tillage practices, including agroforestry, contour ridging, tine tillage and zero tillage in low rainfall areas.

In early 1970s, farmers in the North and South America started experimenting with conservation tillage and even "no-tillage". Using conservation tillage, farmers leave crop residues on the fields after harvest, instead of ploughing them in or burning them off. They plant new crops with special designed planters. These guide the seeds down into a slot in the soil underneath the protective layer of mulch formed by rotting residues.

Because conservation tillage is effective in controlling soil erosion, it helps to reduce losses of nutrients and pesticides that are attached to soil particles. In order to alleviate or reduce some of the disadvantages of conventional farming practice, tillage research has led to the development of a number of conservation farming system which have been tested and promoted in various countries around the world. In early 1970s, farmers in the North and South America started experimenting with conservation tillage and even "no-tillage' (Reij *et al.*, 1996).

Using conservation tillage, farmers leave crop residues on the fields after harvest, instead of ploughing them in or burning them off. They plant new crops with special designed planters that guide the seeds down into a slot in the soil underneath the protective layer of mulch formed by rotting residues (Maltzahn, 1998). Generally the practices can be grouped into four broad categories (Hagmann and Murwira, 1996).

A) Mechanical conservation options: examples include:

- Stone bunds as check-dams in rills and small gullies along the contour lines
- Infiltration pits (pot holes etc.) to retain water and soil from flowing out
- Contour bunds or Fanyu juu terraces for water and soil retention in the field

B) Agronomic (crop) conservation practices

- Weeding system to enable reduction in ploughing
- Inter-cropping and agro-forestry

- Crop rotation

C) Biological or cultural conservation
- Use of manure and compost
- Vetiver grass for rill reclamation and grass strips

D) Conservation tillage practices
- Ridge tillage and tied ridging
- Mulching
- Minimum tillage

Fowler (1999) indicated that only 3[illegible] arable land area of South Africa is classified as being of high agricultural potential. Van der Merwe & de Villiers (1998) indicated that almost 60% of South African soils are having very low organic matter content conducive to land degradation and low productivity. Similar observations were made by Botha (1996) in that these areas are faced with an insidious deterioration of natural resources coupled with rapidly increasing human and livestock. Therefore food production has failed to keep pace with the population growth. With good moisture conservation practices Ciskeian (central Eastern Cape) soils may give modest yields of some crops (Hensley and Laker, 1978).

Conservation tillage has been acknowledged as a more suitable technology for crop production in the commercial farming sector. The commercial farmers in Namibia were reported to have started shifting towards conservation tillage practices over 15 years ago and results have been well-appreciated (Maltzahn, 1998). Some farmers have not only benefited from the increased yield but also increased soil productivity. Methods used to conserve soil and moisture in Namibia include minimum tillage, zero tillage, ridging, mulching and timely weeding.

Conservation tillage systems also utilise cover crops to ensure effective water conservation practices which help to offset soil degrading processes and to maintain soil productivity. Conservation tillage can increase the available water during the growing season through increasing infiltration and reduced evaporation. It enhances crop yields where water is in limited supply (Parr *et al.* 1990).

According to Food of Agricultural Organisation (FAO) (1995), conservation tillage was being practiced on about 45 million hectares, mostly in North and South America. FAO indicated that in South America, both smallholder farmers and big farmers are rapidly adopting the new technology. In some states in Brazil, it is official policy and in Central America, Costa Rica has a Department for Conservation Agriculture in its Ministry of Agriculture.

FAO (1995), stated that there is a great potential for the adoption of conservation agriculture in Africa as a whole. At present, some large farms in South Africa and Zimbabwe are using conservation agriculture, and no-till farmers' clubs similar to those in South America have been set up in South Africa. It is also reported by FAO (1995), that initiatives to promote conservation agriculture for small farmers are under way in Cameroon, Ghana, Kenya, Malawi, Namibia, Tanzania, Uganda, Zambia, Zimbabwe and South Africa.

According to Kumwenda (1999), Malawi practices dryland farming which is characterised by low and unpredictable rainfall. With increasing frequency of drought in the country, lack of adequate rainfall for agricultural production is perhaps the most critical factor currently. Researchers are developing technologies that farmers can use to sustain the productivity at a profitable level, while conserving renewable natural resources. However, these can only be useful if there is rainfall or irrigation facilities. Water is important in crop production, livestock farming, fish farming and for human use.

According to FAO (1995) conservation tillage allows minimum disturbances of the soil while ensuring maintenance of crop residues on the surface. The crop residue left on the surface cushions raindrop impact and reduces water movement, hence soil erosion. As water runoff and evaporation are reduced, water penetration is improved.

The most commonly applied conservation techniques are tie ridging, mulching, no-till and ripping (Shetto, 1999) and Shetto also mentioned other methods used to conserve soil and moisture which include minimum tillage, soil fertility management ridging and timely weeding. Other forms of conservation practices include maize-legume inter-cropping and crop rotation. Extensive research was conducted into strip tillage system, where alternate bands of soil were cropped and kept bare, both under well controlled experimental conditions and in the farmers fields (Kaumbutho *et al.*, 1999).

Tie Ridges

Ridges have traditionally been associated with the growing of specific crops such as potatoes, beans, groundnuts, sweet potatoes and cassava. Ordinary ridges are 20-50 cm high and are usually spaced between 60-80 cm. When they are laid across the slope they control the soil erosion. According to Reij *et al.* (1996), ridges vary in their width, height and direction depending on the topography, soil depth and water flow.

The type of crop to be planted on the ridge and land ownership structure also influences ridge size and shape. Ridges also improve the soil fertility through in situ composting of vegetation that is buried under during ridge formation. Harris *et al.* (1992), in their work in Botswana tried several tillage options including tie ridging and strip tillage. For tie ridging, the system did have effect of preventing redistribution of water within fields, while concentrating water in the farrow bottom.

However, some ridging is used for crops such as groundnuts and sweet potatoes in some parts of the region (Hatibu, *et.al*,1997). In some areas, broad based ridges have evolved furthering more the concept of soil fertility restoration with the incorporation of more grass and trash (Shetto, 1999). In Malawi the ridging constructed by handhoes is the most common practise used by about 95% of the smallholders farmers (Mwinjilo, 1992).

According to Rigourd and Sappe (1998) ridges have been common in Eefa for the last twenty years, and this has been facilitated by the use of animal power and the plough. Zero tillage or no till are not used at all due to costs of herbicides and lack draught and labour resources (Kumwenda, 1990).

Some efforts is being made to reduce labour requirements for construction of ridges by the use of permanent ridges as compared to annual ones.

Ripping

Ripping with oxen is a very old technique and still being practised by lots of traditional farmers in numerous parts of the world using ripper plough. The ripper is a simple implement used to break the soil in spaced rows. The implement only opens a strip leaving other areas undisturbed and seeds are planted along the loosened soil in the rows and then are covered by using a harrow. Unlike ploughing, ripping does not till the full field surface, hence much less soil is disturbed.

Fowler (1999) indicated that early work on conservation tillage in maize production involved stubble mulching and reduced tillage with tines of 'chisel' ploughs. Maize tillage research at Potchestroom (now North West Province) over nine (9) seasons showed that reduced tillage had little or no adverse affect on yields. Fowler (1999) went further on to say that on a sandy soil at Viljoenskroon (now in North West Province) ripping to a depth of 450mm under the row produced significantly higher maize yields during the low rainfall years.

Rippers are also being promoted in Namibia, mainly used as tools to open up furrows for planting in dry lands (Misika and Mwenya, 1999). According to Sakala (1999) ripper plough is used for making planting furrows, either on ploughed or unploughed land and it works fairly well on dry soils and dry, early, planting becomes possible in Zambia.

According to Kaoma-Sprenkels et. al.(1999) planting in lines using an animal drawn ripper tine without prior ploughing is a step in the right direction: much less soil is disturbed than by ploughed. Kaoma-Sprenkels *et.al.* (1999) went further to explain that the soil is only worked in narrow bands, while the surface between these lines is left undisturbed. However, weed infestation problems are likely to arise. Many farmers clean their fields by burning old weeds and the residues of previous crop usually after first having taken away the bulk of stover for use as feed for animals or by allowing their animals to graze on it.

No-till

This conservation tillage system [illegible] minimum disturbance of soil, making of furrows or holes where seed is planted. The rest of the field remains undisturbed and crop residue is left on the ground, which practice reduces soil erosion, causes build up of organic matter in soil and also reduces labour. No-till as the basic technology for conservation agriculture is used to cultivate 52 percent of the arable land in Paraguay, 32 percent in Argentina and 21 percent in Brazil. FAO (1995) indicated that though in absolute terms the biggest area under no-tillage is in the United States of America, it is only slightly over 16 percent of the country's cultivated land and weeds were the major problem.

2.5 Weed control in Conservation Tillage

Weeds, pests and diseases are major limiting factor in crop production in every part of the world (McArthur, 1980). Where heavy infestations occur, these should be greatly reduced or eliminated prior to commencing a conservation system (Findlay,1998). Heavy weed infestations were reported in a tillage system trial at Domboshawa, Zimbabwe (Vogel, 1994a). On conservation tillage systems, particularly clean ripping and mulch ripping, perennials such as couch grass (*Cynadon dactylon*) and Mexican clover (*Richardia scabra*) posed serious problems. Thus a major criticism of conservation tillage systems lies in the problems associated with weed control. All weeds in the conservation tillage land will contribute to water loss and since maize is a grass, it is important to control other grass weeds as early as possible. In Malawi zero tillage or no-till are not used at all due to cost of herbicides and lack of draught and labour resources (Kumwenda, 1990).

Once grass weeds have emerged, control measures in the crop are difficult, with any cultivation being detrimental to the system. A study at Makoholi Experiment Station by Riches *et al*., (1997) found that the weeding effort which accounted for more than 60% of the labour used for maize production in semi-arid Zimbabwe, was gently eased while grain yields and return to weeding labour significantly improved where animal drawn implements such as cultivators and ploughs were used to control weeds. The efficiency of weed control was also found to greatly improve where farmers used re-ridging with the plough as a weed control measure than under no-till tied ridging in the sub-humid north of Zimbabwe (Nyangumbo, 1993).

Complementary work by Shumba *et al.,* (1992) showed that the use of ripper tines for primary land preparation allowed for timely planting but resulted in earlier and heavier weed infestations. Thus, unless effective weed control can be achieved the benefits of timely planting accrued using the ripper tine in conservation tillage system are lost. The relatively higher adoption of conservation tillage in the large scale commercial farming sector could therefore be attributed to the availability of suitable machinery and use of herbicides for weed control (Farmesa, 1998). Herbicides tend to be unaffordable to smallholder farmers in Zimbabwe (Shumba et al.,1992) and their use is very limited. Weed control in conservation tillage systems therefore remains a major bottleneck to smallholder farmers (Beets, 1992).

CHAPTER 3
RESEARCH METHODOLOGY

This chapter outlines the methodology used in the investigation of soil and water conservation farming practices of smallholder farmers in the central Eastern Cape province with special reference to five selected districts. The choice of the study area, questionnaire design, sampling and interviewing procedures and data analysis are discussed.

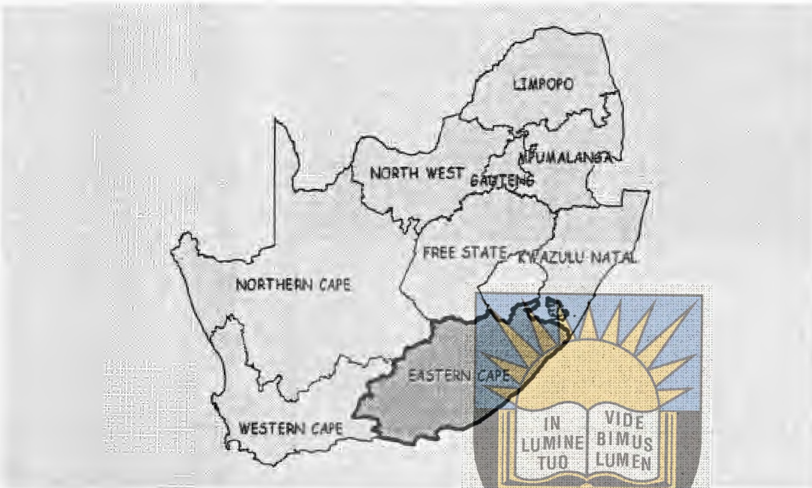
3.1 The study areas

The survey was carried out in five districts in the central region of the Eastern Cape Province, namely, Middledrift, Keiskammahoek, Zwelitsha, Seymour and Hewu districts see (Fig. 3.1). Four small-scale farms were selected for on-farm trials, two farms were from Peddie, dry district and the other two were from Middledrift, wetter area.

The research was conducted in two phases.

(a) a survey using Participatory Rural Appraisal (PRA) techniques and

(b) field trials to test some of technologies that might have a good potential for soil and water conservation in the selected areas.



(I) (Raath J, 2003, GIS, Cradock, E.C.)

(II) (Raath J, 2003, GIS, Cradock, E.C.)

Fig. 1: I Location of Eastern Cape in relation to South Africa.

II Map of Eastern Cape showing the location of the study area.

3.2 Phase 1: Participatory Rural Appraisal (PRA)

3.2.1 Questionnaire objective and design

A coded questionnaire (appendix 1), was used and was designed to achieve the maximum flexibility of the responses. The questionnaire was administered in the form of personal interviews, with an in-built mechanism of getting free response from the interviewees. The questionnaire was designed to give enough information to both the interviewee and the researcher. It was short and straight to the point so that the researcher be able to deal with every question before the interviewee gets bored. This approach permits the interviewer to probe further when particular responses are encountered, as well as allowing subjective assessment and rating to be made of opinions, knowledge and attitudes.

The questions were made simple, straightforward and understandable to farmers. Open ended questions were used in conjunction with closed questions. The questionnaire contained forty-two questions, and the information elicited from the farmers was recorded on the questionnaire.

3.2.2 Sampling procedure

The survey was carried out in all the five districts to assess the existence of and awareness by local farmers of any methods or techniques used for soil and water conservation tillage methods. Participatory Rural Appraisal (PRA) was conducted where village meetings were held for each area and a total of 45 rural households were then identified by local extension officers for participation in in-depth interviews. Three villages were randomly selected in each of the five district and three farmers were interviewed in each village. There was an exceptional case in Seymour because farmers are too scattered and therefore, only nine farmers were selected. The villages chosen have been summarized in Table 3.1

Table 3.1. Districts and villages visited

Districts	**Villages**		
Middledrift	Qibirha	Rewuleni	Ngwenya
Keiskammahoek	Nqolo-nqolo	Lower Gxulu	Rabhula
Zwelitsha	Qhugqwala	Peelton	Gubevu
Seymour	Farm 1	Farm 2	Farm 3
Hewu	Kammastone	Upper Hukuwa	Mthwakazi

The researcher visited the selected households over a period of two months to conduct informal interviews.

3.2.3 Interviewing procedure

During the survey a preliminary meeting was held in each district with the local extension officers together with the village committee members of each village to explain what the survey was about. After the village committee members welcomed the survey they addressed the issue with members of the community as a whole and invited them to participate. In the interviews, detailed information was obtained on socio-economic issues, labour and farm power availability, livestock and land management issues, soil and water conservation practices in use and crop production systems and yields. The information was recorded in the questionnaire designed for this purpose (Appendix 1). Each and every respondent was given enough time to answer questions put to him or her. It even took over than one and a half hour to finish each questionnaire, because the respondent was inturn given enough chance for questions. They indeed appear eager to be able to learn more about the ways of soil and water conservation farming practices.

The interview was conducted in an informal manner for each respondent to become comfortable and respond freely. Most of the questions were discussion type questions. According to Bembridge (1987) this enables the respondents to say whatever they would like to and also helps the interviewer to get more information. The education level of the farmers general was also taken into consideration in the phrasing of questions. English was the language for the questionnaire, while Xhosa, as the respondents' mother tongue, was used to translate for the farmers. The researcher was the only one who did the interviews so as to get the required information. The respondents were randomly selected by the local extension officers, and were selected because of the respondents' interested in agriculture.

3.3. Phase 11: Field experiments

3.3.1 Location of experiments

The potential of using three tillage systems was tested on four small-scale farms in the 1999/2000 cropping season. Two of the farms were located in a relatively dry district, Peddie, with a long-term rainfall average of 570 mm per annum, whilst the other two farms were locates in a wetter district, Middledrift, with a long-term rainfall average of 703 mm per annum. The conservation tillage treatments were compared with the [illegible] normal practice as the control.

The normal practice in the area is to mouldboard plough the fields, either by tractor or animal traction, during the autumn or winter months (a practice locally known as winter fallowing) followed by another ploughing at the beginning of the new cropping season. The tillage treatments were therefore applied on "winter fallowed" lands and were replicated twice on each farm. The plot size was 10 m by 25 m, giving a working area of. 250 m^2 for each plot.

3.3.2 Soils of the experimental sites

Soils in Peddie district were classified as follows: Site one: soil form was Avalon and the family was Kameelbos, with a depth of 85 cm. Site two the soil form was Oakleaf and the family was Caledon, with a depth of 139 cm. Soils of both sites in Middledrift district were classified as follows: soil form was Pinedene and the family was Mariendal with a depth of 80 cm in site one and 85cm in site two. For more details on the soils see profile description given in Appendix 3.

3.3.3 Vegetation

The veld type of the study areas consists of thornveld and grassland with Acacia karroo being the dominant tree species. In most areas the grass cover is dense and of sourish in nature, but in drier areas and on dolerite soils, the veld is generally sweet (Beckerling *et al*, 1975).

3.3.4 Climate

Schultze (1965) and Els (1971) describe the climate of the major part of the Ciskei, viz. The area between the mountains and the Indian ocean, as follows: The climate of this area is temperate to warm and humid with a definite summer rainy season which is at a maximum in March and a minimum in June.

3.3.5 Infrastructure

The physical environment and the existing infrastructure of both districts will be shortly discussed in this chapter. It is very much important to know the climatic conditions of an area you are working with. Any climatic description can only be as good as the data on which it is based. Although irrigation, engineering, fertilization and other technologies may profoundly change the natural agricultural potential of an area, climate, topography and soils remain the prime physical determinants of agricultural systems

(ARDRI, 1989). Development is focused on the creation of local infrastructure such as roads, water supply and electricity. There is, however, still insufficient rural infrastructure in the study areas.

Roads in the study area were constructed with gravel. Roads are very important in any community so that farmers with tractors, carts get access to the fields. The conditions of these roads are poor to very poor such that during wet days one found it impossible to move in the communities especially to the fields.

3.3.6 Treatments and design

The following conservation farming methods were tested and compared to the farmer's conventional practice.

1. **Strip/rip tillage.** A ripper is another soil and water conservation tillage implement being promoted in central Eastern Cape. This is used for making planting furrows, either on ploughed or unploughed land. It saves on time because it only opens the strips for planting and leaves the remaining soil untouched as shown in Figure 3.1.

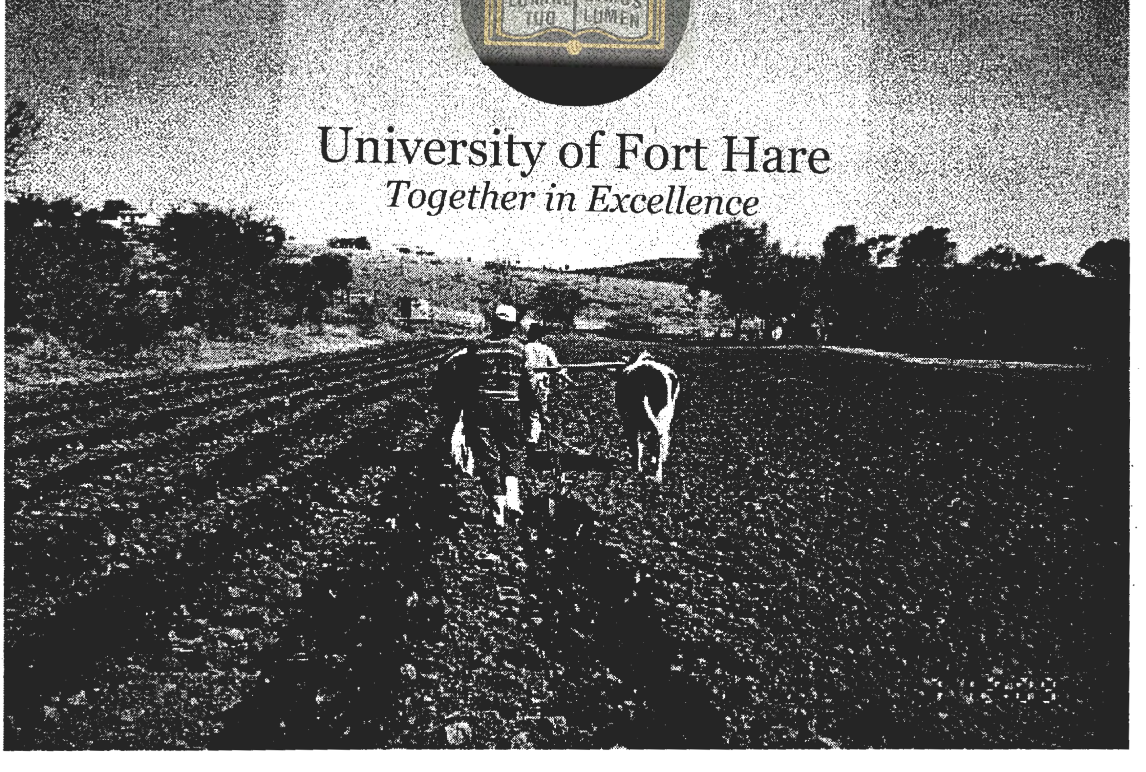


Fig. 3.1 Strip tillage at planting.

2. **Tied-ridging**. This system involves planting on ridges, or ridging up after planting, then blocking the furrows at regular interval. The ridger is the soil and water conservation implement used for making ridges and ridges were tied using hand hoe. This system is a means of trapping rain water. Ridger can also be used for weeding and for harvesting potatoes. The ridger is pulled by the span of four or six oxen depending to the soil structure. If soil is heavy the span of six oxen is required to pull the implement.

Figure 3.2 The structure of tied-ridging techniques.

3. **Pot-holing**. A hand hoe is used to dig pot holes with a spacing of 75 cm x 60 cm. A spacing of 75 cm x 60 cm will give 22 222 stations per hectare, which at two plant per station will give 44 444 plants per hectare see Figure 3.3. The size of a hole was one metre wide and about 7.5 cm deep. The holes catch the moisture or trap the rain water in the area that crops most benefit to, that is the rooting zone. The seeds were planted on the ridges of the hole.

Figure 3.3 The structure of pot holing techniques

The treatments were laid randomly with four replications in each field. The maize cultivar used in these experiments was PAN 6364, which is a hybrid most preferred by the farmers as it is resistant to diseases and drought. According to du Toit and de Bruwer (1994) this cultivar is resistant to smut rust and streak diseases and the estimates average is around 8.0 t/ha in good rainfall areas.

The treatments were laid down in October 2000, and planting was done immediately after the laying out of the treatments. Most of the Eastern Cape farmers prepare their fields in June to keep their land ready for planting in September - November depending on the rainfall. The purpose for leaving the soil bare during winter which precedes the planting of maize is to accumulate a reserve of water in the soil. This is accomplished by making the soil receptive to the rain and by controlling weeds.

3.3.7. Procedure and measurement during the course of the experiment.

Each experimental sites were ploughed and winter fallowed prior to the layout of the treatments before planting in September/October 1999. The different methods used for land preparation were as follows: two oxen were for ripping, four oxen for making ridges, and hand hoes for tied ridges. Hand hoes were used to make up holes for pot-holing technique.

The population crop of the maize was 44 444 plants/ha based on the recommendations by Lienbenberg (1989). The total area of 60 m x 30 m in each field was used for the experiments with a 10m turning space between replicates. The plot size of 25 m x 6 m was used for each treatment. Weeding treatment was carried three time in each field.

During the course of the field experiments about six group meetings were held at each site with local farmers, the main purpose was to access views and farmers evaluation of the different conservation farming techniques. The information was recorded by using diary book and tape recorder. The experiments were monitored weekly and for most of the time the researcher was staying within the villages with the farmers.

3.3.7.1 Soil profile moisture content.

Soil profile moisture content was measured by taking samples with an auger. Soil samples were randomly taken from each plot on the same day of the field activities, that is during planting, weeding, and tasseling stage.

3.3.7.2 Time and Labour input during field activities.

Labour input for tillage, planting, fertilizer application, weeding and harvesting was measured by using time sheets (Appendix 2). For each of these activities the amount of labour was calculated and recorded. Labour for each activity was recorded by the interviewer using recording sheets.

Time was measured by using a stop watch. By the time the operation started the starting time was recorded, if there is a pause the time for the pause was not calculated. This was done to all field operations, to determine which operation was better that the other in terms of time saving.

3.3.7.3 Crop heights and yield.

Crop heights were taken at four different stages of growth. The measurements were taken on a standing plant except during harvesting stage. The reason was that some plants were out of reach.

3.3.7.4 Grain and stover yield.

The whole plot was harvested, s[illegible]ng shelling machine and maize grain was weighed. The grain and stover yields for the soil and water conservation farming practices were compared with the farmer's conventional practice.

3.4 Data analysis

Data was analysed by ANOVA using Mstart progrmme, to find the significances of the trial results.

CHAPTER 4

PART 1: Research survey

4.1 Survey results

4.1.1 Demographic and Agro-ecological conditions.

This chapter briefly describes the demographic environment with special reference to the study area (Fig. 3.1). In the households interviewed four were female-headed and the rest were male-headed. The ages of the respondents in the interview ranged from 38 years to 80 years. The average ages for the different districts are given in Table 4.1. The size of the household ranges from 4 to 11 people, with the majority of being 5 or more people. Most of the people were children (less then 18 years).

Table 4.1: Average size of household, ages, land holding and area of land in operation per district.

District	Av.Ages (year)	Household size	Land holding (ha)	Area ploughed (ha)
Middledrift	66	7	2.0	2.0
Keiskammahoek	63	8	2.1	2.1
Zwelitsha	53	9	2.4	1.8
Seymour	58	7	1.9	1.9
Hewu	57	6	2.6	1.7
Total average	**59**	**7**	**2.2**	**1.9**

Age

Age is one of the important factors in rural development since it indicate the capability of the rural people to participate in agricultural development. Because the needs of and the way an individual thinks and behaves are all closely related to the number of years he/she has lived and his or her age is one of the most important characteristics (Sokhela, 1983). Although chronological age may have an impairing effect on physical capabilities, several research studies have indicated little or no deterioration in intelligence at least up to 60 years of age (Seobi, 1980). Older people have different needs from younger people. They are sometimes less motivated and many have health problems, fewer dependants available for farm work and less inclination to take risk and therefore are less likely to be interested in satisfying more than their subsistance needs (Bembridge,1993).

Household size

The household size is very important as it affects labour supply. The average size of the household ranges from 6-9 and the number of people per household ranges from 4-11.

Land holding and cropping area

The size of the land holding ranges from one (1) acre to four (4) hectors and the average land holding per districts ranges from 1,9 ha to 2.6 ha. The total arable land allocated for farmers was very small but other farmers did not use the entire land. The reasons were the insufficient rainfall, unavailability of labour and farm machinery.

4.1.1.1 Vegetation

The veld type of the study areas consists of thornveld and grassland with *Acacia karroo* being the dominant tree species. In most areas the grass cover is dense and of sourish in nature, but in drier areas and on dolerite soils, the veld is generally sweet (Beckerling *et al,* 1995).

4.1.1.2 Soils

Soils in Peddie district were classified as follows: site one: soil form was Avalon and the family was Kamee[illegible] a depth of 85 cm. site two the soil form was Oakleaf and the family was Caledon, with a depth of 139 cm. Soils of both sites in Middledrift district were classified as follows: soil form was Pinedene and the family was Mariendal with a depth of 80 cm in site one and 80cm in site two. For more details on the soils see profile description given in Appendix 3.

4.1.1.3 Crops and cropping systems

In all areas surveyed, the land which farmers use is under communal land tenure, which means each farmer owns a small piece of arable land for crop production but the grazing land is communally owned and utilised. The cropping area and the residential area have title deeds that are privately owned. The size of the arable lands ranged from 0.6 ha to 4.9 ha, with an average of 2.2 ha, see Table 4.1. The farmers surveyed indicated that they get on average maize yields of 13.2 bags (660 kg) per ha in good year and are about 8.1 bags (405 kg) per ha in bad years (Table 4.2). This was very low because farmers consume green mealies before harvesting. Dry mealies graded and the lowest grade which was used for feeding live stock was not calculated as a yield.

Table 4.2: Maize yield in good and bad years in 50 kg bags/ha (from questionnaire 1997-2000)

Districts	Good Years	Bad years
Zwelitsha	13.5	8.3
Middledrift	11.0	5.0
Seymour	20.0	12.8
Sada	9.3	4.1
Keiskammahoek	12.0	10.0
Mean	13.2	8.1

Farmers perceive a good year when they received a minimum of 560mm of rain and a well distributed rainfall during the growing season and a bad year when the rain water is inadequate for crop production and even if the rain is adequate but not well distributed.

Overall, average yields were not bad except in Sada which is very dry compared to the other areas. Table 4.4 shows the main field crops grown in each district, categorised according to their importance of utilization. Maize is the main crop widely utilised by farmers throughout.

Table 4.3: Main field crops grown in each district ranked according to their importance.

District	Crops grown
Zwelitsha	Maize, potatoes, beans, pumpkins, peas, and lucerne
Middledrift	Maize, potatoes, beans, pumpkins, wheat, and watermelon
Seymour	Maize, potatoes, beans, pumpkins, and butternut
Sada	Maize, potatoes, beans, pumpkins, Lucerne, and watermelon
Keiskammahoek	Maize, potatoes, beans, pumpkins, peas, and oats

Maize is the staple food for the whole Eastern Cape Province and most of the farmers reported that they grow maize for home consumption, any excess that may be available is sold locally. The other crops were used in conjunction with maize products, like stamped mealies and mealie-meal. The predominance of maize was also confirmed in a survey done by O'neill *et al*. (1999) in the Eastern Cape province.

Most of the farmers use animal traction for field operations, as shown in Table 4.3. Farmers reported that they weeded their crops two to three times depending on rainfall, using animals and hand hoes. Animal traction has a long history in agricultural production. It has played, and still plays, an important role in meeting the power requirements of farming systems in many parts of the developing world (Starkey,1995). Those who did not have animals for weeding were planting smaller areas, due to time and labour constraints. With ripping the problem can become worse because most of the soil surface i.e. the space between the ripper lines remain untilled see Figure 3.1. As a result, almost all emerging weeds can continue to grow undisturbed. With regard to land preparation farmers did not have a big problem, the main problematic stage was the weeding and transport to transport manure from the kraals to the fields. Most of the farmers using both manure and fertilizer applied inorganic fertilizer during planting stage.

Table 4.4: Percentage of farmers using different methods of land preparation in five districts of the Eastern Cape Province.

Method	**District**				
	Zwelitsha	Middledrift	Seymour	Sada	Keiskammahoek
Animals only	65	70	82	72	58
Tractor only	0	10	0	15	15
Animals and Tractor	35	20	18	13	37

During the study it was found that the majority of farmers using manure were those who owned livestock, as manure and animal traction for transportation was available.

Table 4.5: Methods used to fertilise the soil and the percentage of farmers using them.

District	Manure and fertilizer	Manure	Fertilizer only	Non-users
Zwelitsha	20	69	11	0
Middledrift	19	56	12	3
Seymour	0	100	0	0
Hewu	0	66	11	33
Keiskammahoek	0	100	0	0

Non-users reported that the reason why they did could not use neither organic nor inorganic fertiliser, was that they did not afford both as they were not having cattle or money to buy the inputs. Another reason for not using was that rainfall is not adequate to dissolve the fertiliser.

4.1.2. Conservation farming practices.

A total of nine farming practices which conserve soil and water were identified as being in current use. Table 4.5 shows the occurrence of the techniques in the districts surveyed in central Eastern Cape Province, while Figure 2 represents the percentage of farmers using the techniques.

Table 4.6: Conservation farming methods practised by smallholder farmers in five districts of the central region of the Eastern Cape.

Conservation Farming Methods	**District where practised**				
Contour bunds	Zwelitsha	Hewu	Seymour	Middledrift	Keiskammahoek
Terracing	+	-	+	+	+
Crop rotation	+	+	+	+	+
Inter-cropping	+	+	+	+	+
Manuring	-	+	+	-	-
Mulching	+	+	-	+	+
Stone bunds	+	-	-	-	-
Winter fallowing	+	-	-	+	+
Furrow ridging	+	-	+	-	-
Planting tree/grass	+	+	-	+	-

Note: + districts where the method was being practised.
-districts where the method not in use.

Contour bunding was widely used because it was constructed by government extension officers. With mulching most farmers were aware but the reason for not using it was that the material for doing it was very scarce especially during winter months.

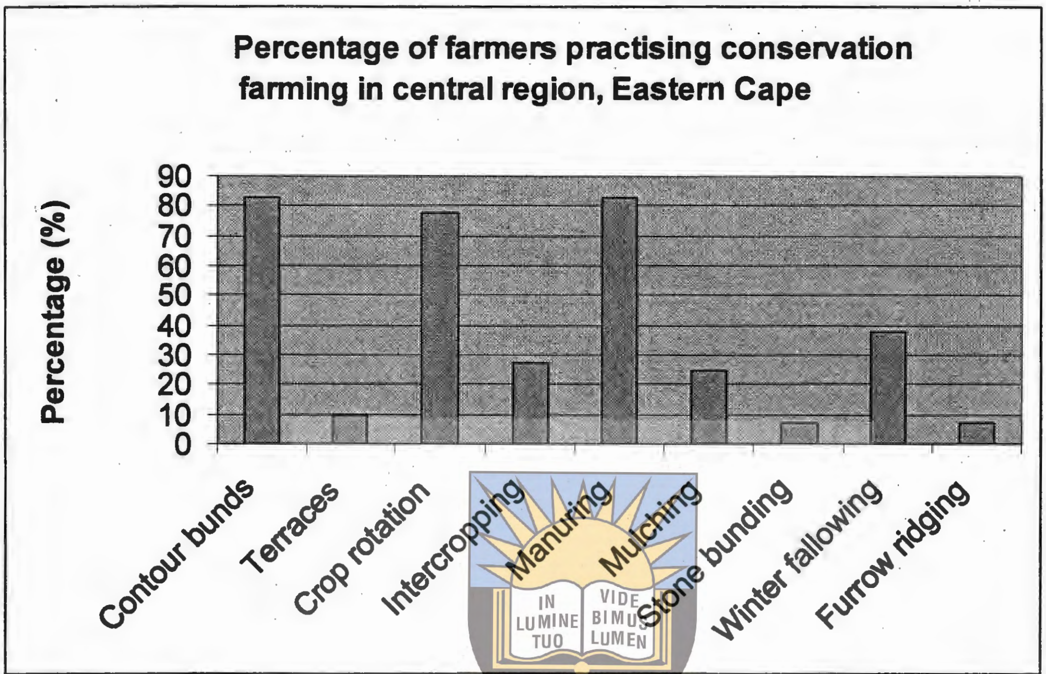


Fig. 4.1: Percentage of farmers practising conservation farming in central region, Eastern Cape.

Similar observations have been found in the northern region of the Eastern Cape province where seven of these practises were identified in a survey conducted by Phillip-Howard and Oche (1996). Figure 3 shows the results of that survey.

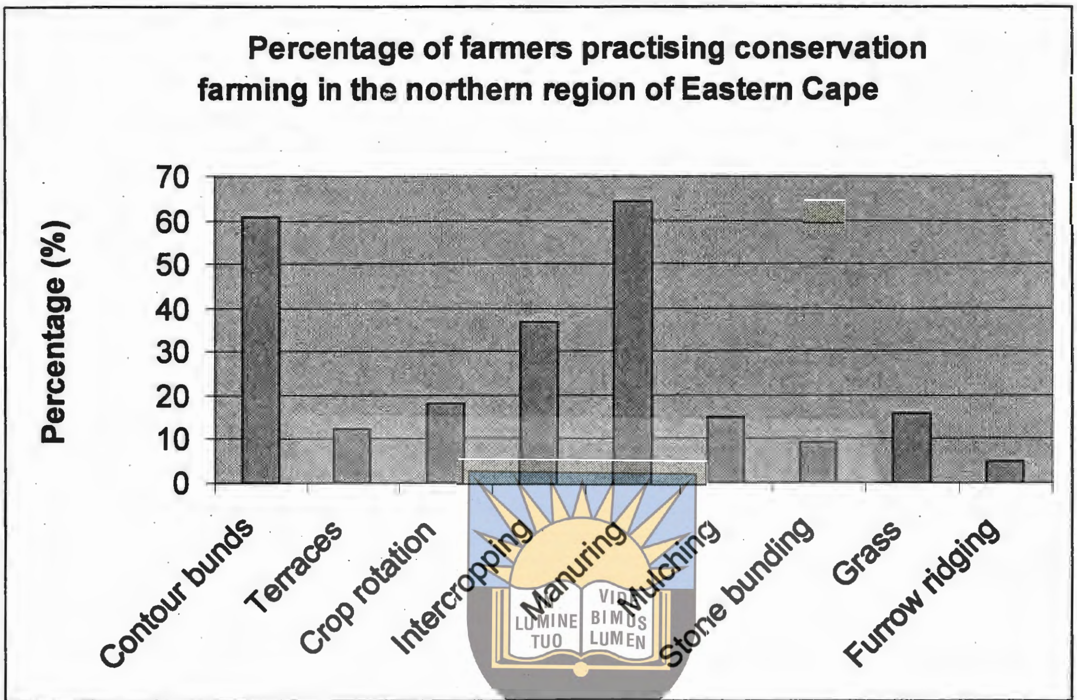


Fig. 4.2: Percentage of farmers practising conservation farming in the northern region, Eastern Cape.

In both regions contour bunding and manuring were the most conservation tillage farming practices, which is being practised by most of farmers (more than 80% of farmers).

PART 2: On-farm experimental results

4.2.1 Rainfall data

Distribution of rainfall received during the experimental period is shown in Table 4.7. Readings were from rain gauges installed at each experimental site and at farmer's home on the day of planting.

Table 4.7. Rainfall distribution during the cropping season in mm at experimental sites in the 1999/ 2000 season.

Month	Middledrift	Peddie
September (1999)	22.5	35.5
October (1999)	47.0	26.5
November (1999)	52.0	22.0
December (1999)	71.0	88.0
January (2000)	82.2	76.0
February (2000)	52.5	96.0
March (2000)	53.5	42.5
April (2000)	123.8	58.5
Total rainfall during cropping season	504.5	445.0

The total rainfall which fell during the growing period (September to April) was 504.5 mm in Middledrift and 445.0 mm in Peddie. The average rainfall during the growing season was above average, as it was confirmed by van Averbeke, *et. al.* 1998, that the total annual rainfall in Middledrift and Peddie varies from 400-700 mm and 400-500 mm respectively.

4.2.2 Profile moisture content

Soil moisture contents taken at three different depths at three different stages of crop growth, viz. planting, weeding and tasselling are shown in Table 4.8. for Middledrift and Peddie districts.
Eight samples were taken in each plot, and dry weight was calculated using oven dry weight.

Table 4.8: Soil moisture contents (% w/w) at three depths (cm) at three different stages of crop development in Middledrift and Peddie districts.

	Middledrift District				**Peddie District**			
Treat-ments	Depth 0-10	Depth 15-25	Depth 30-40	**Treat Mean**	Depth 0-10	Depth 15-25	Depth 30-40	**Treat *Mean***
Profile moisture at planting								
Control	8.11	12.55	15.08	**11.50[a]**	5.36	8.01	7.43	**6.93[a]**
Tie Ridge	7.45	12.32	14.42	**12.39[a]**	5.12	7.27	10.82	**7.74[a]**
Pot Hole	9.63	12.90	15.48	**12.67[a]**	3.80	6.86	8.42	**6.36[a]**
Rip	8.21	12.96	16.07	**12.41[a]**	4.66	7.73	9.55	**7.31[a]**
Mean	**8.35[c]**	**12.55[b]**	**15.08[a]**	11.99	**4.74[c]**	**7.47[b]**	**9.05[a]**	7.08

Profile moisture at weeding								
Control	10.45	13.31	17.06	**13.61** ^{b}	11.88	16.68	18.66	**15.74** ^{a}
Tie Ridge	13.48	15.18	19.09	**15.92** ^{a}	10.61	13.84	20.65	**15.03** ^{a}
Pot Hole	10.36	14.18	15.11	**13.21** ^{b}	9.26	15.08	19.65	**14.66** ^{a}
Rip	10.06	13.75	15.84	**13.22** ^{b}	11.82	21.37	23.89	**19.02** ^{a}
Mean	**11.09** ^{c}	**14.11** ^{b}	**16.77** ^{a}	13.99	**10.89** ^{c}	**16.74** ^{b}	**20.71** ^{a}	16.12
Profile moisture at tasseling								
Control	9.09	13.86	16.07	**13.00** ^{b}	9.76	14.40	15.33	**13.16** ^{ab}
Tie Ridge	11.61	15.36	20.43	**15.80** ^{a}	9.03	10.39	14.84	**11.42** ^{b}
Pot Hole	9.72	14.90	21.47	**15.36** ^{ab}	9.13	12.27	14.10	**11.83** ^{b}
Rip	13.32	14.92	18.54	**15.59** ^{a}	11.35	15.46	17.87	**14.89** ^{a}
Mean	**10.93** ^{c}	**14.76** ^{b}	**19.13** ^{a}	14.94	**9.82** ^{c}	**13.13** ^{b}	**15.53** ^{a}	12.83

Note: Means with the same letter in a row or column are not significantly different at $P<0.05$.

Tillage treatments did not have a consistent effect on soil profile moisture contents. Of note, however, is that in Middledrift district the tied-ridging treatment had a significantly higher profile moisture content than the other treatments both at weeding and tasseling stages though the effect was non significant at planting. The inconsistence of the data may be attributed to sampling errors as well as delays between sampling and the laboratory weighings (sometimes samples were only processed the following day). This kind of data is best collected by means of neutron moisture probes in "permanently" installed access tubes.

Measurement of crop heights as an indicator of crop performance generally showed that, bigger plants were found in control plots and smaller ones in ripped plots throughout the season, though the effect was not always significant (Table 4.9). Plants increased in height considerably from an average of 52 cm at weeding to 130 cm at tasseling with little further increase to about 160 cm at harvest.

Table 4.9: Height of plants (in cm) taken at three different stages of crop development in the Middledrift and Peddie districts.

	Middledrift District			***Peddie District***		
Treatment	**Height at weeding**	**Height at tasseling**	**Height at harvest**	**Height at Weeding**	**Height at 2nd weed***	***Height at harvest***
Control	53^{a}	138^{a}	160^{a}	51^{a}	82^{a}	177^{a}
Tied-Ridge	53^{a}	120^{b}	155^{a}	55^{a}	81^{a}	175^{ab}
Pot Hole	52^{a}	124^{b}	152^{a}	55^{a}	80^{a}	176^{ab}
Rip	48^{b}	124^{b}	157^{a}	47^{a}	69^{b}	165^{b}
Mean	**52**	**126**	**156**	**52**	**79**	**173**

Note: Numbers with the same letter e.g (a) in a column are not significantly different at $P<0.05$.
* Crops replanted and were not yet at tasseling stage at time of sampling.

Average grain, stover and total biomass yields under the different tillage treatments in the two districts are shown in Table 4.10. Significantly ($p<0.05$) higher yields were obtained under the tie-ridge and pot hole systems than with the rip and farmer's systems, although the effects were non-significant for grain in Peddie district.

Table 4.10: Average grain, stover and biomass yields under the different tillage treatments in the two districts.

	Middledrift District			*Peddie District*		
Treatment	**Grain Yield kg/ha**	**Stover Yield kg/ha**	**Biomass kg/ha**	**Grain Yield kg/ha**	**Stover Yield kg/ha**	**Biomass** *kg/ha*
Control	2 680 ^{b}	3 960^{ab}	6 640	2 467^{a}	3 520 ^{b}	5 987
Tie Ridge	3 268^{a}	4 626^{a}	[illegible]	2 621^{a}	3 991^{a}	6 612
Pot Hole	3 220^{a}	3 946^{ab}	7 166	2 563^{a}	3 954^{ab}	6 517
Rip	2 813 ^{b}	3 446	6 259	2 387^{a}	3 498 ^{b}	5 885
Mean	**2 995**	**3 995**	**6 990**	**2 510**	**3 741**	**6 251**

Note: Numbers with the same letter in a column are not significantly different at P<0.05.

Average labour requirements for the field operations of land preparation, fertilizer application plus planting, and weeding are given in Table 4.11 Labour requirements were virtually identical in both districts for each of the operations, giving some measure of confidence in the accuracy of the data collected. Of the three operations, fertilizer application taken together with planting (seed placement and covering) demands the least labour input under all the tillage systems, except the rip system which has least labour demand at stage of land preparation.

Table 4.11: Labour requirements (in man hours per ha) for different operations under different tillage systems measured in the two districts.

	Middledrift District				*Peddie District*			
Treat-ment	**Land Prepn**	**Fertilz. & Plant**	**First Weeding**	**Total man hrs/ha**	**Land Prepn**	**Fertilz & Plant**	**First Weeding**	**Total man hrs/ha**
Control	133 [c]	30 [c]	4 649 [b]	**4 812**	147 [c]	33 [c]	4 573 [d]	**4 752**
Tie Ridge	270 [b]	126 [a]	5 572 [a]	**5 967**	229 [b]	123 [a]	5 306 [a]	**5 657**
Pot Hole	1 717 [a]	137 [a]	5 511 [a]	**7 365**	1 701 [a]	132 [a]	5 669 [a]	**7 503**
Rip	38 [d]	84 [b]	4 875 [b]	**4 997**	34 [d]	83 [b]	4 629 [b]	**4 746**
Mean	**539**	**94**	**5 152**		**528**	**93**	**5 044**	

Note: Numbers with the same letter in a column are not significantly different at P<0.05.

Weeding had the highest labour demand, especially under the two water conservation systems of tied-ridging and pot-poling in which all the work was done manually in order to conserve the structures of each. Pot-holing demanded a lot of labour at the land preparation stage because this was done completely by hand without resort to use of animal draught power. This demand could be considerably reduced by the development and use of appropriate animal-drawn equipment as in case of ridging. Since the tying of ridges was done by hand, the labour input went slightly up, but this operation could also easily be mechanised. Labour demand for weeding was significantly reduced in conventional (control) and rip systems by, first, use of the animal-drawn cultivator between crop rows, followed by hand hoeing within the rows.

CHAPTER 5
DISCUSSION

This study has attempted to assess the extent of using conservation farming methods under smallholder farming conditions in the central region of Eastern Cape Province. The study has revealed a number of issues. Firstly, smallholder farmers in the study area extensively use cattle as their main source of draft power. A similar survey conducted by O'Neill *et. al.* (1999) also indicated that about 80% of farmers in the area are currently using draft animals. Because of past Government mechanisation programme in Eastern Cape, most small-scale farmers did not have draught animals. Tractors were seen to be used as a complementary to animal draught power. Therefore, a shortage of draught animals coupled with shortage of ox-drawn cultivator has been a major cause of poor weed control and hence low crop yields (O'Neil, et.al., 1999; Taylor, 1999; Israel *et al*, 1999)

Secondly, most farmers interviewed were aware of some farming practices which conserve soil and water as well as their benefits. Lack of knowledge is one of the constraints that farmers have. The low output was brought about essentially because the farmers lacked technical know-how, credit and essential services such as extension services necessary to boost their outputs.

The main techniques currently in use are the earth contour bunds, manuring, crop rotation and inter-cropping. Few farmers practice mulch tillage and the use of stone bunds. Labour was not perceived as a major constraint but the lack of fencing of arable land, as well as birds and rodent damage were cited as the main problems. Some farmers did not have enough family members to provide the labour to control weeds. Such farmers made different arrangements for controlling weeds, by either hiring labour from the villages or organising oxen for cultivation. Okigbo, (1978) found that traditional farming systems in Africa consisted of a more or less concentric pattern of the fields on which were practised various methods of fertility maintenance, fallowing, clearance systems tillage, production of different numbers of species and varieties of crops and animals. The farming system in central Eastern Cape was characterised by low agricultural production.

A big problem was the lack of water for crop production. Water is both an economic resource and a basic requirement to sustain life. In rural areas access to water is considered as a basic human right, because people who are living in rural areas are interested in agricultural production for their economic development. The development of rural areas, particularly by adopting water sources should be South Africa's greatest asset.

Most of the smallholder farming areas in Eastern Cape is environmentally delicate and thus susceptible to degradation as a result of high population pressure and poor land use practices. The natural resources of the country constitute a national asset which is essential for the economic welfare of the present and future generations. Eastern Cape is poorly endowed with high-quality agricultural land and water resources. Agricultural development depends on how these two assets are conserved. Farmers, both large and small-scale, are the principal users and primary custodians of these resources. The Government will encourage intergrated land-use planning and community participation to ensure optimum management and utilisation of natural resources.

Most of the farmers were unaware of minimum tillage techniques such as ripping and zero tillage. The on-farm trials on tie ridging, pot-holing and ripping using draft animals were well received by farmers and provide an alternative in soil and water management initiatives.

Six group meetings were held in each village to assess farmers perception against the field trials. With the ripper plough most of the village farmers saw the advantage of time and labour saving. Farmers were using the ripper plough to plant their fields, meaning that the ripper was already adopted by the farmers.

The unavailability of the implements was one of the farmers constraint in adopting the technology. For example with the tied-ridging farmers were willing to adopt the technology but the unavailability of the plough seem to be a problem. Although farmers saw yield advantage with tie- ridging but the problem is the labour consuming during weeding process as it is evidenced in Table 4.11

There is a need to investigate further the effect of soil and water conservation farming practices on morphological parameters of component crops because, the knowledge might help in elucidating yields obtained under different soil and water conservation farming systems. The results of the experiments showed that tie-ridging was the best method that conserves more water and also a better yield was obtained.

In traditional farming systems, the farmers practice contour bunding because government extension officers constructed these contour bunds. Farmers claimed that these structures are good in conserving soil. One of the main reasons for using contour bunds was that it helps the farmers to calculate their field areas easily. The bunding was constructed with an area of about 0.745ha between each bund.

One of the main constraints in promoting conservation tillage is weed control and the unavailability of crop residuals and cover crops, which can be used as mulch. However, there is a need to investigate more on the implements or the most affordable way of weeding (Dibbits & Wanders, 1998). Farmers prefer to use crop residues such as maize straw to feed their livestock rather than leaving them on the ground as mulch.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Worldwide, conservation tillage practices have been the general solution to the traditional crop production methods that invert the soil and destroy its structure. Land degradation, both arable and grazing land should be given due consideration. Conservation tillage has been practised by many farmers worldwide as a traditional method to sustain soil fertility and reduce tillage energy requirements. A lot of advantages have been realised in agricultural production with the conservation tillage concept, which have greatly increase production worldwide. For example, in Uganda, like in many other countries in East and Southern Africa, conservation tillage practices have increased crop production especially in the dry-land areas through the increase of stored water and minimise labour, energy and capital requirements in agricultural production (Lubwana, 1999).

Tie-ridging and pot-holing systems were effective in water conservation and utilization by plants as reflected in increased yields; however, this former function could not be verified by corresponding increases in soil profile moisture contents, possibly due to sampling errors or a limited depth of sampling. In spite of these advantages, the two tillage systems incurred a very high labour input demand because of the associated reduction in, or complete lack of, use of animal draught power. Small-scale farmers who already face acute labour constraints viewed the high labour requirements of these conservation tillage systems negatively. This poses a considerable hindrance to their adoption and use by the farmers. Therefore the promotion of conservation farming practices that enhance soil fertility and water use efficiency, reduce energy and labour requirement and sustain the environment should be given high consideration and high priority for the improvement of agricultural productivity of smallholder farmers in the central region of the Eastern Cape province.

With good moisture conservation practices Ciskeian (central Eastern Cape) soils may give modest yield of some crops (Hensley and Laker, 1978). South Africa could not grow well without water and agricultural production. Agricultural sector is dependent upon finding water for economic growth. The scarcity of water in the central Eastern Cape region created a strong failure in the development process.

On-farm demonstrations and farmer training are required to popularise the minimum tillage techniques as an alternative to soil and water management initiatives. Conservation of water resources is an important element in productive agriculture, and a major consideration in dry land areas where rainfall is barely adequate to support crop cultivation with less than 250mm annual rainfall. As was confirmed by farmers in Peddie that sometimes they were not able to plant due to unavailability of rainfall. Farmers must have technologies to conserve all available water.

The supply of water in rural areas may be considered as productive investment or growth aspects and as consumption facilitating redistribution of income as well as uplifting the standard of living. There is a need for farmer centred, on farm, participatory promotion methods and publicity, for sensitisation, and environmental education, marrying traditional knowledge, ideas and practices, while addressing accompanying fears of users, farmer exchange visits, identifying suitable equipment's and promoting the same nationally and regionally, field testing by farmers in multi-disciplinary and multi sectoral research, geared towards quantifying the real gains of conservation tillage. Technology transfer efforts need to capture environmental protection through gender sensitive soil management techniques and planning (Kaumbutho *et al.*,1999). The propose strategies towards an improved conservation systems which will improve or facilitate weed control should be given a high consideration.

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APPENDIX 1

CONSERVATION FARMING PRACTICES QUESTIONNAIRE

Date of interview ______________________________

Name of the farmer: ___________________________

1. **Place of interview:** ____________________________

2. **Gender of the respondent:**

1	2
M	F

3. **Age of the respondent:** ___________________________

4. **Marital status**

1	2	3	4
Married	Single	Divorced	Widow/er

5. **Household size** ___________

no. of

1	2	3	4
A.M	A.F	C.M	C.F

6. **What is the size/ total area of your arable land (field)?**

_________ **ha**

7. **What is the actual area for ploughing?**

_________ **ha**

8. **What crops do you usually grow?**

Crop	Area of land	Use

9. When do you normally plough your fields?

____

10. How long do you normally take to plough your land?

____

11. Do you practice intercropping?

1	2
Yes	No

12. If yes, which four major crops do you intercrop?

____

____

13. Do you practice crop rotation?

1	2
Yes	No

14. If yes, which four major crops do you rotate?

____

____

15. What advantage do you see in crop rotation and intercropping?

____

____

16. Do you use manure?

1	2
Yes	No

17. Why yes/no?

____

____

____

18. Do you use fertiliser?

1	2
Yes	No

19. Why yes/no?

____

____

20. Have you changed your view on the use of manure and fertilizer since you started using then?

1	2
Yes	No

21.If yes, explain

____

____

____

22. How often do you weed your crops?

____

____

23. **Who performs the following different tasks?**

	Male	Female	Child		labour	
			Boy	Girl	M	F
Ploughing						
Planting						
Weeding						
Fertilizer application						
Harvesting						
Marketing						

24. **Do you ~~have~~/ obtain enough labour?**

Yes	No

25. **If no, what are the problems?**

____

____

26. **What methods do farmers in this area use to minimize water loss from their lands?**

____

____

27. **What methods do farmers in this area use to minimize soil loss from their lands?**

____

____

28. In your opinion do these methods practices really conserve soil and water?

1	2	3	4
Yes	No	Does not know	Little bit

29. Who put in place the conservation structures?

1	2	3	4
Households	Community	Government	Project

30. Do you receive enough rainfall for your crop production?

1	2
yes	no

31. If no, what problems do you experience apart from inadequate rain?

____

____

____

____

32. Is it possible to indicate the yield for the maize crops?

	Good year	Bad year
Maize		

33. **What happen to the crop residues after harvest?**

____

____

34. **Are you familiar with crop cover/ mulching methods for soil and water conservation?**

1	2
Yes	No

35. **If yes, mention them**

____

____

36. **Do you use any animals for draft purposes?**

1	2
Yes	No

37. **If yes, which animals are used for draught purposes?**

____

____

38. **Have you ever stop using them?**

1	2
Yes	No

39. **If yes, why?**

____

____

40. **Did you ever use or hire tractor?**

1 2

Yes	No

41. If yes, how much you pay to plough with hired tractor?

(costs) R ______________ per ha

42. How are the following operations performed?

Operation	Tractor	Animal	Both	Hand
a) Primary tillage				
b) Secondary tillage				
c) Planting				
d) Weeding				
e) Open new land				
f) Harvesting				
g) Other (specify)				

APPENDIX 2

Soils of the experimental sites

Site 1 (Middledrift)

Soil classification

- Soil type - Sandy loam
- Soil depth 80cm
- Soil form Penedene – Orthic A
  yellow-brown apedal B
- Soil family – Mariendal

Site 2 (Peddie)

- Soil type – Sandy loam
- Soil depth – 85 cm
- Two soil form – Avalon and Oakleaf

Orthic A
Avalon –Yellow-brown Apedal B
Soft plintic B

- Soil family – Kameelbos

Oakleaf- Orthic A
Neocutanic B

- Soil family - Caledon