UPSCALING OF RAINWATER HARVESTING AND CONSERVATION ON COMMUNAL CROP AND RANGELAND THROUGH INTEGRATED CROP AND LIVESTOCK PRODUCTION FOR INCREASED WATER USE PRODUCTIVITY

J McCosh, L Dedekind, Z Ntombela, M Khuzwayo, B Letty, Z Shezi, N Bambalele and N Gasa
With contributions from: T Everson, C Everson, N Dlamini, N Sosibo and M Malinga



WATER RESEARCH COMMISSION
TT 712/16

UPSCALING OF RAINWATER HARVESTING AND CONSERVATION ON COMMUNAL CROP AND RANGELAND THROUGH INTEGRATED CROP AND LIVESTOCK PRODUCTION FOR INCREASED WATER USE PRODUCTIVITY

Report to the

Water Research Commission

and Department of Agriculture, Forestry and Fisheries

by

J McCosh, L Dedekind, Z Ntombela, M Khuzwayo, B Letty,

Z Shezi, N Bambalele and N Gasa

With contributions from

T Everson, C Everson, N Dlamini, N Sosibo and M Malinga

Institute of Natural Resources

WRC Report No. TT 712/16

February 2017

Obtainable from

Water Research Commission

Private Bag X03

Gezina, 0031

orders@wrc.org.za or download from www.wrc.org.za

The publication of this report emanates from a project entitled *Upscaling of rainwater harvesting and conservation on communal crop and rangeland through integrated crop and livestock production for increased water use productivity (K5/2177)*

ISBN 978-1-4312-0880-7

Printed in the Republic of South Africa

Acknowledgements

The research team firstly thanks and acknowledges the funding support for this research work provided by the Water Research Commission (WRC) and the Department of Agriculture, Forestry and Fisheries (DAFF). In particular, the responsiveness and support provided by Dr Backeberg is acknowledged.

The insights and guidance provided by the Project Reference Group is also gratefully acknowledged. Members of the reference group were

Dr GR Backeberg:	Water Research Commission (Chairman)
Prof CS Everson:	University of KwaZulu-Natal
Dr C Madakadze:	University of Pretoria
Mr JA Denison:	Umhlaba Consulting Group (Pty) Ltd
Prof LD van Rensburg:	University of Free State
Prof N Monde:	University of Fort Hare
Dr S Mpandeli:	Water Research Commission

The assistance of Dr Tafadzwa Mabhuadi with the application of the AquaCrop model in the research is also acknowledged.

The assistance and collaboration provided by the residents of Ntshiqo in the Eastern Cape and of Fabeni and Mxheleni in KwaZulu-Natal is also gratefully acknowledged. In the Eastern Cape, we would like to specifically acknowledge the contributions and support by iNkosi Luthuka in welcoming the project team to work in Ntshiqo and iNdunankulu Zakwe and iNkosi Mchunu for providing us with access to research sites in Muden. The enthusiastic support provided by Mr Mawethu Tshabu to in Ntshiqo is also acknowledged. To the farmers who made their land available and participated in the rainwater harvesting demonstrations, in the Eastern Cape Ms Portia Mjali, Ms Gloria Quvile, Ms Madosini Nkompela, Mr Kenneth Beya and Mr Baweni Sokhombela; and in KwaZulu Natal, Mr Xoshimpi Zulu, Mr Mntungane Zulu as well as Mrs Mavis Ngqulunga and the Mxheleni women's group, we are grateful for your interest, enthusiasm and willingness to test new ways of doing things.

Executive Summary

Rainfed agriculture dominates world food production and thus rainwater harvesting and conservation (RWH&C) has the potential to provide significant social, economic and environmental benefits. This is particularly relevant in sub-Saharan Africa where 93% of farmed land is rainfed. RWH&C is the process of concentrating rainfall as runoff from a larger catchment area to be used in a smaller target area. Collected runoff is either applied directly to an adjacent field or is stored in some type of reservoir and has the potential to increase crop and livestock water productivity.

Micro-catchment RWH&C is a subset of RWH&C techniques and includes the systems and practices which concentrate rainwater from a larger area to a smaller area within a specific field and stores this runoff in the soil profile. Water conservation systems that enhance the productive use of harvested rainwater are considered important complementary practices that should be applied when in-field RWH&C systems are established.

It is in this context that this research project was conducted. The overall objective of this project was to:

1. Review and demonstrate rainwater harvesting and conservation methods for integrated crop and livestock production at field scale for increased crop and livestock water use productivity at two or more selected sites in communal rural areas of South Africa.

The specific objectives of the research were:

2. To evaluate appropriate methods of rainwater harvesting and conservation for sustainable crop and livestock production at field scale.
3. To determine the social, cultural, institutional and organisational status quo and dynamics influencing access to communal cropland and rangeland for up-scaling of appropriate rainwater harvesting and conservation methods.
4. To determine the current levels of productivity and relationships between rain-fed field crop production and livestock production on rangeland.
5. To demonstrate appropriate rainwater harvesting and conservation techniques and practices at field and rangeland scale for improved integrated crop and livestock water use productivity.
6. To evaluate socio-cultural, institutional-economic and bio-physical requirements and opportunities for outscaling for field crop and livestock production with rainwater harvesting and conservation.

There is a general consensus that productivity of croplands in communal tenure areas in South Africa has declined largely due to socio-economic and biophysical constraints (notably, rainfall or lack thereof). From a socio-economic perspective, abandonment of land can be attributed to rising input costs and lack of access to finance, lack of labour (particularly family labour) and land administration and management. While cost increases and lack of labour are attributable to broader economic drivers, a key factor appears to be the inability of traditional rules to be

enforced, resulting in the mismanagement related to the administration of communal tenure land. Another factor is the unwillingness of land holders to lease land to others for productive purposes for fear of losing user rights to that land. The development of improved land administration systems is a necessary local measure to enhance the potential use of agricultural land in communal tenure areas. There is also some evidence that government social grants, by reducing reliance on agricultural production, are contributing to the abandonment of land.

Livestock still play an important cultural, spiritual and economic role in rural areas. The erosion of authority related to the enforcement of traditional rules is problematic and traditional authorities are often not able to exert their authority when it comes to the administration of common property resources. Continuous grazing systems as applied in communal tenure areas can be as productive as rotational grazing systems. Either system is subject to the same environmental constraints, most notably, rainfall. Arid and semi-arid rangelands are resilient systems and recover rapidly after periods of drought. The degree to which a grazing system is effective rests largely on how it is managed, and this depends on social and institutional considerations, such as commitment to management, the goals of the management system and the ability of actors to effectively manage the system.

The methodological approach to conducting this research involved a participatory action research (PAR) approach, in conjunction with biophysical assessment of RWH&C. The research was conducted at two sites, Ntshiqo in the Eastern Cape and Muden in KwaZulu-Natal. For the cropping research, rainfall, soil water and crop yield were recorded and analysed to evaluate crop water productivity. AquaCrop was used to model the water productivity of the RWH&C systems tested. With the livestock research, the effect of resting of rangelands and supplementary feeding were evaluated for their potential to increase livestock water productivity (LWP).

The yield results suggest that RWH&C is one of the cropping systems that can be adopted to improve production in low yielding rainfed areas. International research findings are that improving productivity of water in low yielding rainfed areas would result in multiple benefits for rural farmers. This was manifested at Muden (Mxheleni), especially, where RWH&C improved yields and reduced soil erosion. Results from some of the sites indicated a decline in yield indicators in the RWH&C treatments. These observations were inconsistent with literature and expectations.

The results of 2013/2014 at Ntshiqo showed an interesting pattern with respect to harvest index. Harvest index is defined as a proportion of biomass allocated to grain and it is a measure of the plant’s efficiency with respect to the source sink balance. Rainwater harvesting and conservation showed lower grain yield and biomass compared to control, but the harvest index was higher. This might be attributed to RWH&C improving the efficiency of the crop with respect to channelling assimilates from the source to the sink. This concept would however, need further research.

The crop failures observed at Fabeni (KwaZulu-Natal) were due to severe drought conditions experienced during the time of the demonstrations. According to the Bioresource information Fabeni receives about 600 mm of rainfall per annum. Climatic data obtained from an Automatic Weather Station installed on site indicated that in 2014/15 and 2015/2016, only 428.9 and 323.6 mm of rainfall were received per annum respectively. During the critical stages of crop development, the maximum temperatures were above 35°C.

In terms of outscaling, growing food was highlighted as very important for farmers at both sites. High summer temperatures and rainfall were noted as important constraints to production by farmers. The other major constraint raised by farmers was lack of money to purchase inputs. Additional challenges mentioned by some farmers included controlling of weeds, which is a difficult process for the mainly older farmers, lack of information and knowledge of new agricultural practices, pests and hail damage.

Age is often mentioned as factor affecting adoption of new technologies and that younger people are more likely to adopt new technologies than older people. Farmers at the research sites felt that age was not a factor influencing adoption, but observations at the sites revealed a noticeable lack of youth involvement in cropping. It is unlikely that youth will adopt RWH&C given their reluctance to engage in homestead and field crop production. It is likely that importance of growing food will be a greater driver of adoption than age as a factor affecting wider adoption of RWH&C.

From an institutional perspective, tenure security was not considered to be a factor influencing adoption of RWH&C by farmers. Extension support is a challenge, as limited extension support is provided to farmers by the provincial departments of agriculture. Extension officials are not highly motivated to support farmers, except through state-funded programmes. The project team actively involved the local extension officers and there seemed to be some interest in the research. However without a formal government funded programme, it is unlikely that there will be significant support for RWH&C from the provincial departments of agriculture.

Socio-economic assessments highlighted that farmers prefer to make use of tractors and RWH&C was considered to be more costly than normal land preparation due to the extra work associated with the construction of contour ridges. Farmers also perceived RWH&C to have higher labour requirements, particularly in terms of controlling weeds in the spaces between the maize rows used for runoff generation. Most farmers interviewed employ labour to assist with weeding, and felt that there will be greater cost burden associated with RWH&C. One option to reduce this cost is to make use of herbicides to control weeds. However, many farmers know little about the correct handling and application of herbicides, which presents a health and safety risk. Training on the proper use of herbicides would be required.

Even in the face of higher costs, results from all interviews, questionnaires and focus group discussions at the farmers' day revealed that farmers considered the extra benefits associated with RWH&C to be greater than the extra costs. Overall there were positive sentiments in relation to RWH&C and a lot of interest in adopting the technology.

Recommendations provided by farmers for increasing adoption indicate that out-scaling initiatives should focus on influencing government policy and programme development at Municipal, Provincial and National scale. Building capacity within the Department to assist farmers to establish RWH&C is also important. Finally, on-going demonstrations and training are also necessary to enhance upscaling and outscaling.

.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF TEXT BOXES

LIST OF ACRONYMS

ADF	Acid Detergent Fibre
ADT	Agricultural Development Technician
AFDB	African Development Bank
AHT	Animal Health Technician
ARC	Agricultural Research Council
AU	Animal Unit
AUE	Animal Unit Equivalent
AWS	Automated Weather Station
B	Biomass (Above Ground)
BKB	Boere Korporasie Beperk
CAHW	Community Animal Health Workers
CC	Canopy Cover
CGC	Canopy Growth Coefficient
CGC	Crop Growth Coefficient
cm	Centimetre
CP	Crude Protein
CWP	Crop Water Productivity
DAFF	Department of Agriculture, Forestry and Fisheries
EC	Eastern Cape
ECDRDAR	Eastern Cape Department of Rural Development and Agrarian Reform
ECFRC	Eastern Cape Rural Finance Corporation
ECRDA	Eastern Cape Rural Development Agency
EO	Extension Officer
ET	Evapotranspiration
ET_0	Reference Evapotranspiration
FAO	Food and Agriculture Organisation
FC	Field Capacity
FGD	Focus Group Discussion
FSG	Farmer Support Group
GM	Genetically Modified
ha	Hectare
HI	Harvest Index
IDP	Integrated Development Plan
IFRW	In-Field Rainwater Harvesting
ISCW	Institute for Soil Climate and Water
IWMI	International Water Management Institute
K	Potassium
kg	Kilogram
Ks	Water Stress Coefficient

Ksat	Saturated Hydraulic Conductivity
KZN	KwaZulu-Natal
KZNDARD	KwaZulu-Natal Department of Agriculture and Rural Development
LAI	Leaf Area Index
LM	Local Municipality
LSU	Large Stock Unit
LWG	Livestock Working Group
LWP	Livestock Water Productivity
m	Metre
MDG	Millennium Development Goals
MFPP	Massive Food Production Programme
mm	Millimetre
N	Nitrogen
NDF	Neutral Detergent Fibre
NERPO	National Emerging Red Meat Producers Organisation
NGO	Non-Government Organisation
NWGA	National Woolgrowers Association
NWP	Nutritional Water Productivity
OPV	Open Pollinated Variety
P	Phosphorous
PAR	Participatory Action Research
PRA	Participatory Rural Appraisal
PWP	Permanent Wilting Point
R	South African Rands
RWH&C	Rainwater Harvesting and Conservation
SASA	South African Sugar Association
SAT	Saturation
SCO	Stock Control Officer
SSA	Sub-Saharan Africa
SWC	Soil Water Content (gravimetric)
T	Transpiration
TA	Traditional Authority
Tn	Minimum Daily Temperature
Tx	Maximum Daily Temperature
USD	United States Dollar
WHC	Water Holding Capacity
WP	Water Productivity
WRC	Water Research Commission
ZAR	South African Rands

1 INTRODUCTION

This report details the outcomes of a four year research project investing the upscaling of rainwater harvesting and conservation in communal crop and rangelands through integrated crop and livestock production for increased water use productivity.

The main objective of the research project was to:

1. Review and demonstrate rainwater harvesting and conservation methods for integrated crop and livestock production at field scale for increased crop and livestock water use productivity at two or more selected sites in communal rural areas of South Africa.

Specific objective of the research were:

2. To evaluate appropriate methods of rainwater harvesting and conservation for sustainable crop and livestock production at field scale.
3. To determine the social, cultural, institutional and organisational status quo and dynamics influencing access to communal cropland and rangeland for up-scaling of appropriate rainwater harvesting and conservation methods.
4. To determine the current levels of productivity and relationships between rain-fed field crop production and livestock production on rangeland.
5. To demonstrate appropriate rainwater harvesting and conservation techniques and practices at field and rangeland scale for improved integrated crop and livestock water use productivity.
6. To evaluate socio-cultural, institutional-economic and bio-physical requirements and opportunities for out- scaling for field crop and livestock production with rainwater harvesting and conservation.

Elements of objective 5 and 6 were not fully achieved, specifically the demonstration and testing of RWH&C at field scale. Instead, RWH&C was demonstrated at homestead garden scale due to a variety of constraints that prevented the demonstrations occurring in cropping fields. These are discussed in more detail in Chapter 4.

This report consists of seven chapters. Chapter two provides an extensive review of the literature, including defining RWH&C and discussing different systems of RWH&C. The concepts of crop water productivity (CWP) and livestock water productivity (LWP) are explained and factors influencing the adoption, upscaling and outscaling[1] of RWH&C are discussed from a technical and socio-economic perspective. Chapter three details the research methodology adopted at the research sites, including biophysical, social and institutional approaches applied. Chapter four discusses social, cultural, institutional and organisational dynamics influencing access to and use of communal land based on field research, workshops

[1] Note: Upscaling refers to expansion or wider adoption of the technique from smaller areas to larger areas within the same area (e.g. from homestead to cropping fields, or from one homestead/field to many homesteads/fields). Outscaling refers to the expansion of the technique from one area to another area (e.g, to a new village / community)

and focus group discussions with farmers in Ntshiqo (EC) and Muden (KZN). Chapter five details the findings of the water productivity research from a crop and livestock water productivity perspective. Chapter six evaluates the socio-cultural, institutional – economic and biophysical requirements for outscaling the practice of RWH&C. Chapter seven concludes the report by summarising the findings, documenting lessons learnt and providing recommendations for further research.

2 REVIEW OF THE LITERATURE

The review of the literature firstly defines RWH&C and considers techniques and designs for rainwater harvesting. Approaches to site selection, implementation and strategies for promoting and facilitating the uptake of rainwater harvesting are discussed.

The review also defines water use productivity in crop and livestock production systems and considers the linkages between the two production systems. A conceptual framework for understanding the influence of rainwater harvesting on crop and livestock productivity is provided as a basis for identifying biophysical measurements necessary for evaluating the impact of identified rainwater harvesting techniques that are applied at the project sites.

In addition to this the review also considers the social, institutional, cultural and economic factors that may influence the introduction, adoption, upscaling and outscaling of RWH&C.

2.1 Defining rainwater harvesting and conservation

There are numerous definitions of rainwater harvesting (RWH) provided in the literature. A few examples are provided below:

- Boers and Ben-Asher (1982) define RWH&C as 'a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions.'
- Critchley and Siegert (1991) define water harvesting as 'the collection of runoff for productive purposes.'
- The International Water Management Institute (2003) defines RWH&C as 'the collection and/or concentration of runoff for productive purposes. It includes all methods of concentrating, diverting, collecting, storing, utilising and managing runoff for productive uses. Water can be collected from natural drainage lines, ground surfaces, roofs for domestic uses, stock and crop watering.'
- Oweis et al. (1999) define RWH&C as 'the process of concentrating rainfall as run-off from a larger catchment area to be used in a smaller target area. This process may occur naturally or artificially. The collected run-off water is either directly applied to an adjacent agricultural field (i.e. stored in the soil root zone) or stored in some type of on-farm storage facility for domestic use and for supplemental irrigation of crops.'

A review of recent WRC research reports (e.g. Everson, et al., 2011; Botha et al., 2014; Denison and Wotshela, 2009; Monde et al, 2012) reveals that the definition used by Oweis et al. (1999) is the most commonly used definition for RWH&C in South Africa. Denison and Wotshela (2009) note that definitions of RWH&C do not separate rainwater harvesting techniques from two other agronomic practices that deal with soil water relations, namely irrigation (or supplementary irrigation) and soil and water conservation, suggesting that there is substantial overlap between these three practices.

2.2 Making the case for rainwater harvesting

Rainfed agricultural systems dominate world food production and are practiced on 80% of the world's physical agricultural area and generate 62% of the world's staple foods. Upgrading and developing rainfed agriculture can provide significant social, economic and environmental benefits, particularly in relation to poverty reduction. Estimates indicate that 25% of the increased water requirement necessary to attain the 2015 hunger reduction target for the Millennium Development Goal (MDG) can be contributed by irrigation. The remaining 75% will have to come from investments in rainfed agriculture (Rockstrom et al., 2007).

Water shortages are a severe problem for millions of people around the world. In sub-Saharan Africa, it is estimated that 200-500 million m^3 of rainfall is lost in the form of runoff each year (AFDB, 2008), while 93% of farmed land in Sub-Saharan Africa is rainfed (Rockstrom et al., 2007). Low and erratic rainfall threatens food security of farmers who do not have irrigation. In Southern Africa, water is one of the main factors limiting food production (Botha et al., 2007). Resource poor households and communities are most affected by low and erratic rainfall as dry periods erode household capital and ability to bounce back from livelihoods shocks.

With increasing population and growing unemployment in South Africa, combined with low and erratic rainfall in many places, RWH&C has the potential to improve, or at least stabilise agricultural production in communities that depend on agriculture for their livelihoods

Botha et al. (2007) note that the ability to harvest rainwater can empower individuals and communities to secure a better livelihood for their families. Successful RWH&C can also reduce poverty and contribute to the better management of water at household and community level. Proper management of rainwater also contributes to integrated water resources management as it enhances groundwater recharge, balances water resources demands, and favours ecological sustainability.

When considering food security, an increasing number of households in South Africa are not able to afford an average nutritionally adequate food basket. The depth of food insecurity varies within and between households and the food security status of a household and its members is very sensitive to livelihood shocks (short duration) and stressors (long duration), and thus changes over time (Altman et al., 2009). Food price inflation also affects food security. The Food and Agriculture Organisation (FAO, 2009) noted that the sudden increase in food prices in 2007-2008 increased the number of food insecure people globally from 900 million to more than 1000 million. Chronically food insecure and low income households are more vulnerable to food price shocks as a higher proportion of income is spent on food. This means that that households who were marginally food secure prior to a shock might fall into severe transitory or severe chronic food insecurity afterwards, which may require emergency interventions. Altman et al. (2009) point out that given the seeming depth of household food insecurity, food security targets should be established that aim to reduce poverty and facilitate basic human development. Small scale and subsistence agriculture is identified as an option to contribute to incomes and/or savings, as well as to encourage food diversification. With 2.5

million households engaging in subsistence and small scale agriculture, measures that can strengthen own production of food, ideally at a low-cost, with low input levels and of high nutritional value is greatly needed. RWH&C can contribute towards increased production and enhanced food security.

Botha et al. (2007) found that RHW&C improved crop yields and resulted in higher crop diversity, contributing to household food security and higher incomes. Furthermore farmers, who applied RWH&C were found to be healthier, better educated and had better social interactions. Similarly, the African Development Bank (2008) notes that RWH&C can provide benefits for the watering of livestock where pastoral herders operate, as well as for cropping purposes, particularly where rainfed agriculture produces low yields, runoff is unacceptably high, and where food security is inherently low. The International Water Management Institute (IWMI, 2011) points out the following benefits associated with RWH&C:

- Empowers people in rural communities to fight food insecurity and poverty.
- Can increase crop yields by 30 - 110%.
- Can decrease the risk of crop failure by 43 - 63%.
- Can result in a 48 - 54% higher probability of breaking even where crops are sold.
- Is socially acceptable (Increases income, promotes education, improves social well-being, improves health status, reduces crime and increases crop diversity).
- Is easy to implement with low maintenance cost.
- Provides simple, duplicable techniques.

Consequently, the literature suggests that effective implementation of RWH&C techniques has the potential to stabilise and increase crop yields, enhance food security and income generation, while also building social and institutional capital in rural communities in South Africa.

2.3 Defining and categorising RWH&C techniques

Oweis et al. (1999) note that while the blanket term 'water harvesting' is used in many different ways by different practitioners, RWH&C systems should include the following components (Oweis et al,, 1999; Hatibu and Mahu, 1999):

1. A runoff producing catchment.
2. A runoff collection scheme.
3. A runoff storage facility.
4. A cultivated or cropped area.

Where the water is harvested from (scale) and the question of how the runoff is stored (storage) is also important. Consequently, scale and storage descriptors are a good starting point for categorising RWH&C techniques (Oweis et al., 1999; Hatibu and Mahu, 1999).

2.3.1 Scale descriptors

A key differentiation between different rainwater harvesting techniques is the source of the runoff, which can be divided into micro-catchment and macro-catchment, which are described in more detail below.

Micro-catchment RWH&C

Micro-catchment RWH&C involves the concentration of overland flow or runoff from a small or short catchment length, usually between one and thirty metres in length. The runoff generated in the micro-catchment is low. Consequently, there are no provisions for overflow and the water generated is stored in the soil profile, often with the assistance of mulch and other forms of water conservation. Micro-catchment RWH&C is used primarily for replenishing soil moisture to increase crop production and enhance soil conservation (AFDB, 2008). Other terms used to describe micro-catchment RWH&C include:

- In-field rainwater harvesting.
- In-situ rainwater harvesting (or conservation).

Micro catchment techniques are often considered water conservation as they aim to prevent runoff from an area by keeping the water in-situ to allow for infiltration (AFDB, 2008). As a result, conservation agricultural practices are often lumped with micro-catchment RWH&C and it is often argued that micro-catchment RWH&C is achieved mainly through conservation tillage (e.g. AFDB, 2008). Based on the Oweis et al. (1999) definition of RWH&C as 'concentrating runoff', soil and conservation practices are not strictly RWH&C systems, but are an integral part of a rainwater management system.

The other important micro-catchment system is the harvesting of rooftop rainwater, which is used primarily for domestic purposes, although in some cases is also used for small scale irrigation and livestock watering (Figure 2.1).

Figure 2.1: Micro-catchment rainwater harvesting and storage from rooftop rainwater

Macro-catchment RWH&C

Macro-catchment rainwater harvesting involves the capture and diversion of rainwater from outside the cropping area. Overland flow or runoff can be harvested from catchments of areas ranging from one tenth of a hectare to thousands of hectares. The runoff is diverted from farmlands, hillsides, pastures, homesteads, watercourses and roads. The water that is generated can be placed in fields and stored in the soil profile, but can also be stored in ponds, tanks and aquifers. Due to the larger catchment area, provision must be made for the overflow of excess water.

Other terms used to describe macro-catchment RWH&C include:

- Ex-situ rainwater harvesting.
- Ex-field rainwater harvesting.

2.3.2 Storage descriptors

Rainwater harvesting can also be categorised based on where it is stored and when it is used. Oweis (2004) suggests that RWH&C should be divided, based on storage (location and timing), into two broad components, namely on-farm water harvesting, or supplemental irrigation water harvesting

On-farm water harvesting (Runoff farming)

On-farm water harvesting deals specifically with the storage of water within the soil profile where water is directly available to the plant. It is often also called runoff farming or in-field rainwater harvesting. Often mulches and other soil amendments (e.g. incorporation of organic matter) are used in conjunction with this to increase infiltration and soil water holding capacity.

Supplemental irrigation

Supplemental irrigation is a form of water harvesting that aims to modify the timing of water application and involves the use of a storage system other than in the soil (e.g. dams, water tanks) for use at a later stage.

Supplemental irrigation is defined as the application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth, to increase and stabilise yield. The additional water alone is inadequate for crop production (Oweis et al., 1999). In other words it is a short term intervention for periods of shortage, during which the crop would die, or yields would be substantially depressed by moisture shortage. Thus supplemental irrigation ensures that the productivity of rainfall is maintained by ensuring that crop yield reductions or losses are prevented by short term irrigation interventions during the growing period.

Figure 2.2 provides an overview of the different scale and storage techniques. This review focuses on, micro-catchment RWH&C. For the sake of consistency and to align with commonly used WRC descriptions, the categorisation and terminology provided by Oweis (2004) will be used to describe different rainwater harvesting systems. The focus of this research project is on rainwater harvesting and conservation at field scale and thus the research will consider micro-catchment, on-farm rainwater harvesting methods and associated soil and water conservation systems.

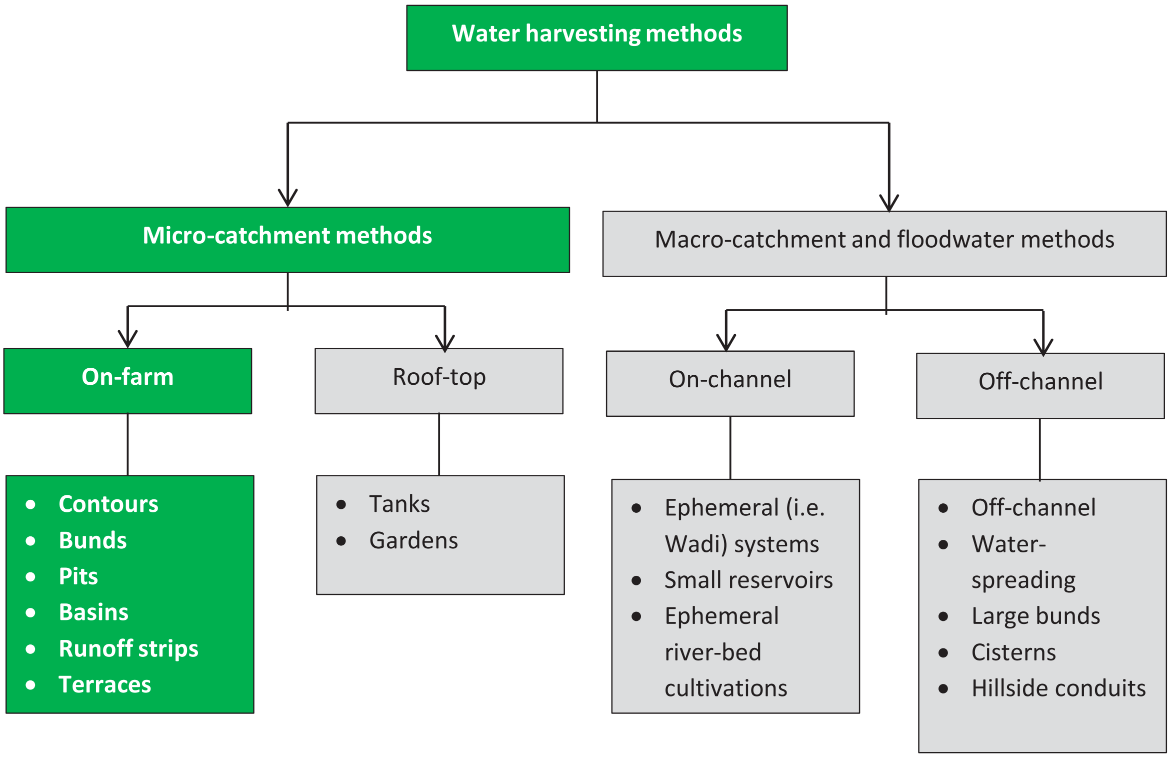


Figure 2.2: Categorisation of water harvesting methods – this research project focussed on micro-catchment on-farm RWH&C techniques, shaded in green (After Oweis, 2004)

2.3.3 Complementary practices

According to Rockstrom et al. (2007), the application of RWH&C as a tool for improving water management is often not by itself sufficient. At farming systems scale, a full response to water harvesting investments will only be achieved if other production factors, such as soil fertility, crop varieties and tillage practices, which increase plant water uptake, are also improved. Important yield improvements are also better achieved through synergies for example when water management is linked to organic fertilisation from agroforestry and livestock systems. Thus, while micro-catchment RWH&C practices have potential for increasing and stabilising yields in rainfed agriculture, the application of the system should not be considered in isolation from other production factors.

Rockstrom et al. (2007) suggest that dual rainwater management strategies should be applied to enhance crop production. These are (1) increasing plant water availability and (2) increasing plant water uptake capacity. Options for improving these are described in more detail in Table 2.1.

Table 2.1: Rainwater management strategies (Rockstrom et al., 2007; adapted from Critchley and Siegert, 1999)

Aim	Rainwater management strategy	Purpose	Management options
Increase plant water availability	External water harvesting systems	Mitigate dry spells, protect springs, recharge groundwater, enable off-season irrigation, permit multiple uses of water	Surface micro-dams, subsurface tanks, farm ponds, percolation dams and tanks, diversion and recharging structures
	In-situ water harvesting systems, soil and water conservation	Concentrate rainfall through runoff to cropped area or other use	Bunds, ridges, broad-beds and furrows, micro basins, runoff strips.
		Maximise rainfall infiltration	Terracing, contour cultivation, conservation agriculture, dead furrows, staggered trenches
	Evaporation management	Reduce non-productive evaporation	Dry planting, mulching, conservation agriculture, intercropping, windbreaks, agroforestry, early plant vigour, vegetative bunds
Increase plant water uptake capacity	Integrated soil, crop and water management	Increase proportion of water balance flowing as productive transpiration	Conservation agriculture, dry planting (early), improved crop varieties, optimum crop geometry, soil fertility management, optimum crop rotation, intercropping, pest control, organic matter management.

In the next section, RWH&C techniques are described. The chapter details micro-catchment, on-farm RWH&C practices, some macro-catchment techniques and also presents some complementary practices that can be used to enhance the productivity or RWH&C systems.

2.4 Rainwater harvesting and conservation techniques

This section explores a range of micro- and macro-catchment techniques, including some indigenous or local adaptation practices. The section is divided into (1) micro-catchment techniques, (2) macro catchment techniques that are potential applicable at a field scale and (3) complementary water conservation methods.

2.4.1 Micro-catchment, on-farm rainwater harvesting techniques

There are a range of micro-catchment RWH&C techniques that can be applied for RWH&C. Many are quite similar and simply have variations based on the country or region from which they originate. A variety of authors describe different techniques that are used (e.g. Critchley and Siegert, 1991; AFDB, 2008 and Denison and Wotshela, 2009; Oweis et al., 2012; Denison et al., 2011; Botha et al, 2014).

The main types of micro-catchment rainwater harvesting systems are described briefly below. They are categorised according to broad categories as follows:

- Runoff strips.
- Bunds and contour-type techniques.
- Terraces.
- Planting pits and basin-type techniques.

Runoff strips

Inter-row rainwater harvesting (also known as runoff strips) is used primarily on flat lands or gentle slopes. These systems generally comprise bunds or ridges constructed along the contour and a small runoff generating catchment area that delivers water to the water storage area.

<u>In-Field Rainwater Harvesting (IFRW)</u>

Matangwana is the Sotho name for this RWH&C technique that was developed by the Agricultural Research Council (ARC) – Institute for Soil, Climate and Water (ISCW) (Botha et al., 2014). This falls into the runoff strip category of micro-catchment RWH&C and consists of a two-metre wide runoff strip between alternate crop rows, where water is collects and infiltrates in the basin at the end of the runoff strip, as shown in Figure 2.3. Organic material or stones can be included in the basins to further conserve water, while mulch along the runoff strip reduces soil movement and suppresses evaporation. Once the basins have been established, no-till practice is applied to the land, which results in a crust developing on the soil surface. Rainwater is therefore concentrated around the plants when they are growing and fully grown crops, with an expanded root system, can also access water stored in the soil volume underneath the runoff strip.

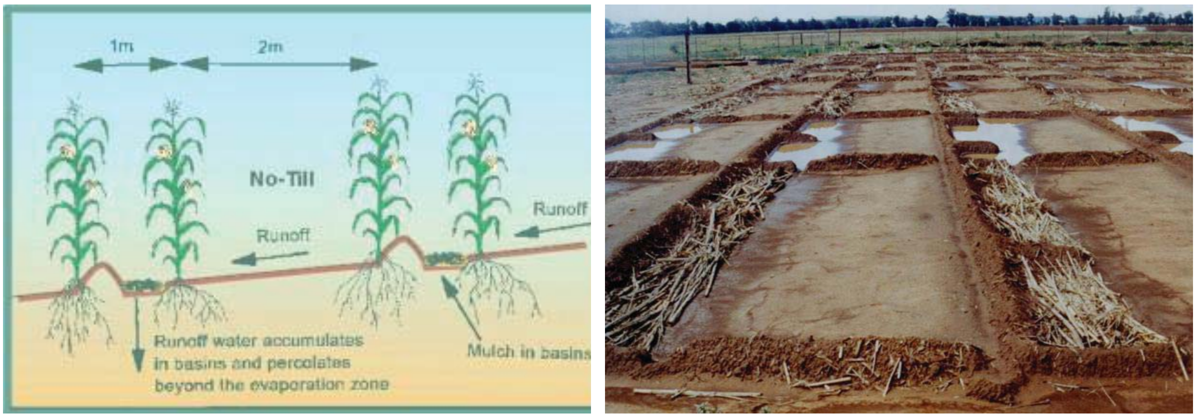


Figure 2.3: Matangwana runoff strip in-field rainwater harvesting technique (Botha et al., 2007)

In field trials over six seasons at Thaba Nchu in the Free State, this technique was found to increase maize and sunflower yields by as much as 50% (Botha et al., 2007).

Mechanised basins

The mechanised basin requires a tractor and a specially modified tractor drawn implement. The specialised implement creates basins for the collection of rainwater. The plough has a basin attachment which pivots on the rear of a three-point hitched ripper. The scraper at the rear of the attachment creates the basins. The ripper tine operates directly in front of the attachment to break up compacted soil. Downward movement of the attachment is limited by a chain, thus enabling the tractor to lift the whole machine clear of the ground. When the ripper tine is engaged, the shaped control wheel controls the movement of the scraper blade, resulting in a row of basins being created.

Bunds and contour type techniques

Contour bench terraces

Contour bench terraces are used on lands with steep slopes (20-50%). Each terrace is constructed with a bench terrace below a flat planting area. Above the planting area, steeper non-cropped areas generate runoff to be collected in the cropped area. The terraces also play an important role in soil and water conservation by reducing runoff velocity and spreading runoff along the terrace. Due to the steep slopes and risk of excess runoff, drainage points are placed along the terrace to release excess water. Contour bench terraces are used mainly for trees and bushes and are rarely used for field crops.

Contour bunds and ridges

Contour bunds and ridges are similar to bench terraces but are generally used on slopes that are less steep. The distance between the contours ranges from 5-20 metres, depending on slope. One or two metres of the space directly above the ridges is used for crop production, with the balance being used as a runoff generating area. It is critical that the bunds follow the line of the contour exactly to ensure even distribution of runoff, otherwise runoff is generated along the bund, which can result in overtopping and breaking of the bund at lower points, or pooling of water in certain areas along the contour.

Contour stone bunds

Stone bunds are constructed along contours to reduce runoff velocity, spread the runoff across the slope and increase infiltration. A small trench is dug along the contour and large rocks are placed in the trench as a foundation and on the downslope portion of the trench. Progressively smaller stones are placed in the upstream half of the trench to limit water flowing through the stone bunds.

Semi-circular and trapezoidal bunds

These are small semi-circular or trapezoidal bunds, whose arms face upslope. They are staggered along the contour to capture excess flow from above, but each bund should be sufficiently large to generate enough runoff to provide for the crop without additional runoff. These are used mainly for rangeland rehabilitation or fodder production, but can be used for growing trees, shrubs and field crops. Semi-circular bunds are also known as demi-lunes (Figure 2.4).

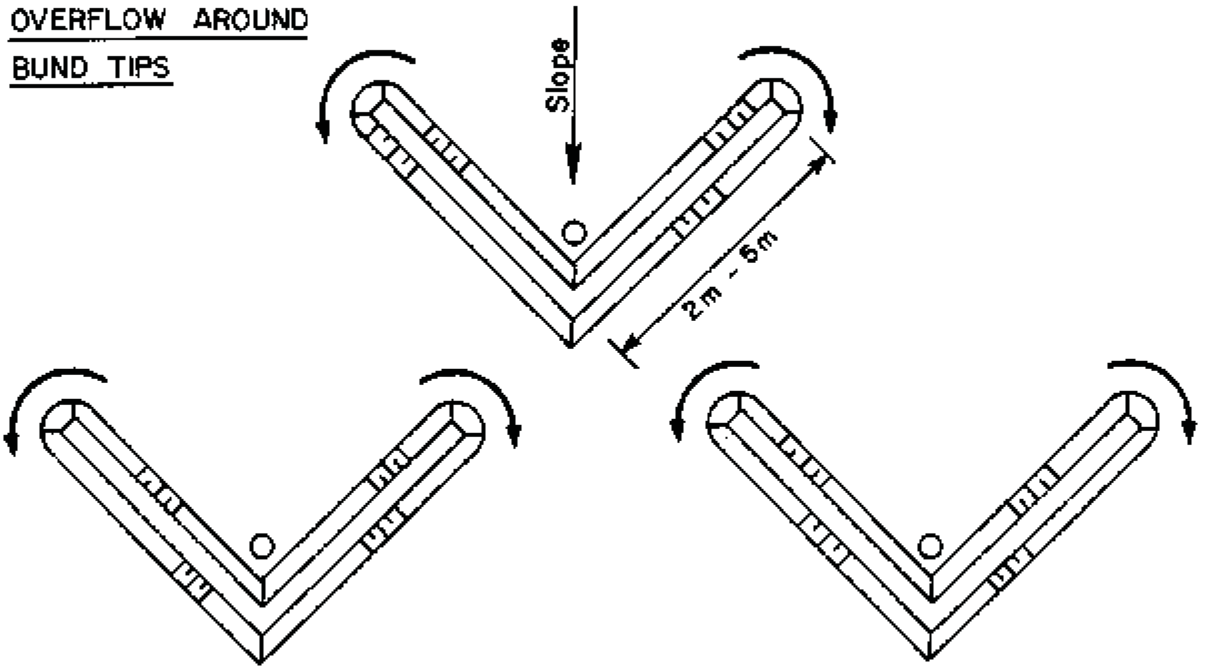


Figure 2.4: An example of triangular bunds (Source: www.fao.org)

Variations on these kinds of bunds include eyebrow terraces, where stones are used to support the side of the semi-circular bunds and rectangular bunds, which have three perpendicular borders with the arms facing up the slope.

Text Box 1: Tied ridges

Tied ridges are a technique that is often applied to prevent water running along the contour line in contour based RWH&C practices. Where good alignment with the contour cannot be achieved, cross-contour bunds (or ties) can be placed at regular intervals along the bunds to prevent the lateral movement of water. Tied ridges or cross contour bunds are commonly used in runoff strip and bund-type rainwater harvesting systems (Figure 5).

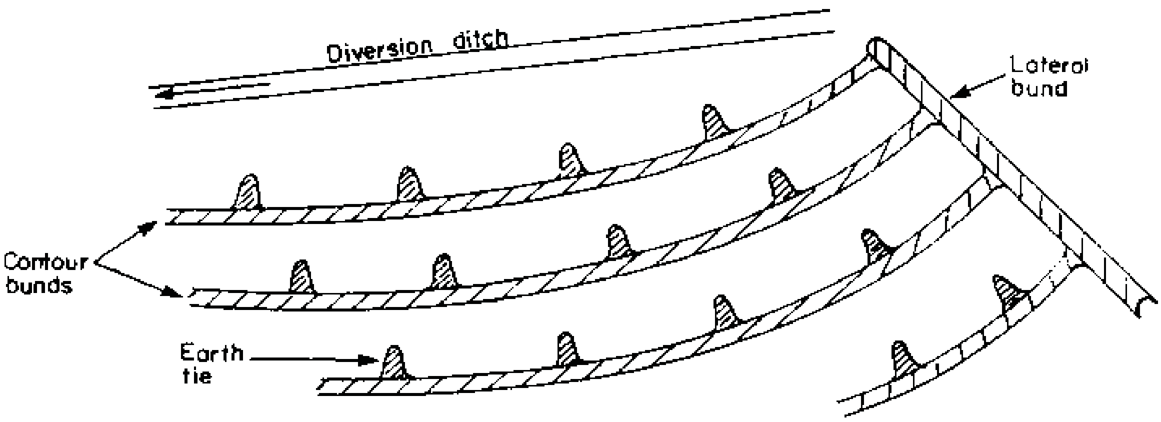


Figure 2.5: Diagrammatic representation of tied ridges or earth ties (Source: www.fao.org/docrep/U3160E/u3160e1c.gif).

Fanya-juu Terracing

Fanya-juu are used in Kenya and are so named because 'juu' is the Swahili word for 'up'. When these terraces are built, at trench is dug along the contour and the soil is thrown up-slope to create an embankment that acts as a runoff barrier and creates a trench below the embankment. The bunds are usually stabilised with fodder grasses, and where available, stones are also used to stabilise the bunds. Diversion furrows can be used to supplement rainwater falling on the terraces. Over time, gradual erosion and redistribution of the soil creates a terrace above the embankment that was created. Crops such as bananas, pawpaws, citrus and guava are grown in the ditches below the bunds, where soil water content is highest.

Stone terracing

Terracing involves the enclosing of portions of land using rocks and stones to conserve soil and manage water flows on steep slopes. Other materials can also be used, such as old tyres. Stones are usually stacked at the lower end of the lands and usually extend up the slopes along the boundary of the field. Over time, the stone terraces are back-filled with soil in a step-like formation, which increases soil depth, reduces slope and increases soil moisture. Stone terracing must allow for the safe disposal of excess water during high rainfall events. Excess water should discharge parallel to the terrace structures into a drainage line that is protected against gulley erosion by using stones, brush packing or vegetated waterways.

Text Box 2: Local example of stone terracing

A local example of stone terracing is reported by Denison and Wotshela (2009). In Gogela village, Kokstad, KwaZulu-Natal, the removal of rocks from stony cultivated lands over time, combined with the increasing demand for cultivated land resulted in rocks being placed on the boundaries of cultivated lands. At the same time, it was noted that erosion and runoff from land was occurring, resulting in the placement of the removed stones at the lower ends of the lands becoming a common feature at the beginning of the nineteenth century, with each household constructing and managing its piece of terraced land, ultimately resulting in improved soil conservation, water availability and crop productivity.

With the advent of National party government's betterment and rehabilitation schemes, previously haphazard terraces became more formalised as households were reallocated equal sized plots of land of approximately 1 ha in a block fashion along contour lines. This resulted in a more formalised terrace / contour system that prevented water from cascading or rilling onto downstream lands. Associated with this is the deposition of fertile soil in the lower portions of the terraces resulting in higher fertility and more productive land compared with the upper parts of the fields.

Planting pits and basin techniques

The use of planting pits is an old system and has a number of variations, which are discussed below.

<u>Zai Pits</u>

The Zai pit is probably the best known application of planting pits and is made up of small pits, into which manure and grass is mixed to increase water holding capacity and fertility. Planting pits are used primarily for the cultivation of annual crops, particularly cereal crops and are commonly used on flatter lands with slopes up to 5%. Pits have to be re-formed every year and thus have a relatively high labour requirement. Other names for these pits include Cholo, Matengo and Ngoro pits (Figure 2.6).

<u>Katumani pits</u>

This manual pitting system was developed in Kenya. It is similar to the zai pit and semi-circular bunds, but the micro-catchments are constructed as interlocking bunds of about 2 m^2 each. The pits can be extended down and along the slopes as necessary, with final embankments being about 300 mm high. Katumani pits are used primarily for the revegetation of degraded grazing areas and some crops (e.g. bananas) using rainfall as low as 300 mm per annum. The pits do require protection from livestock while grasses are establishing.

Figure 2.6: Zai planting pits (Source: http://pool.howtopedia.org/images/f/fa/WA-pit-300.jpg)

Ploegvore

Ploegvore ('plough furrows') are a form of pitting, which has been used for centuries in east and West Africa, although they are a recent introduction to South Africa, where it has been adapted for mechanisation using the 'happloeg', using an adapted single disc plough. The ploegvoer system involves creating numerous small, well-formed pits in the soil which collect rainwater, seed, sediments and plant litter. The pits also create a favourable microclimate for plant growth. The ploegvoer system is used mainly for grazing and degraded land and the system was developed and tested as part of a soil conservation drive in the arid west in the 1960s and 1970s. This programme was considered successful, with dramatic visual improvements. Ploegvore require careful mechanisation and the selection of suitable lands, where slope is not too steep (Denison and Wotshela, 2009).

Negarim basins

Negarim basins are small, diamond shaped basins, bordered by earth bunds. This system and variants thereof are widely used in arid and semi-arid regions of the world, particularly sub-Saharan Africa. They are placed along the slope so that two points of the diamond are parallel to the contour, meaning that runoff flows and collects in the lowest point of the diamond. They can be constructed on a range of slopes, but there is risk of erosion and loss of bunds at slopes greater than 10%. This can be resolved by increasing bund height, however this may not be economical from a labour perspective. Negarims are best suited to growing tree crops, although they are also used for rangeland rehabilitation and for fodder trees in reforestation (Figure 2.7).

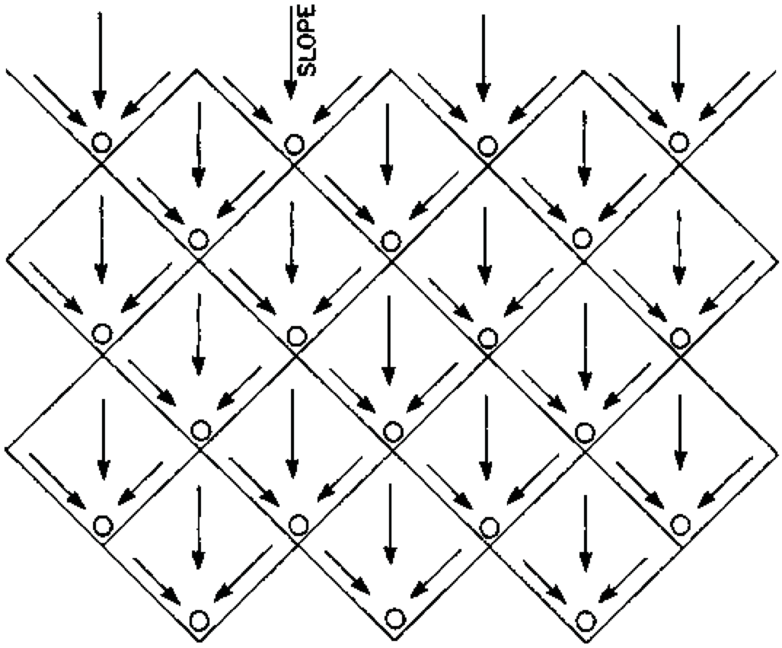


Figure 2.7: Negarim basins (source: www.fao.org/docrep/U3160E/u3160e14.gif)

Fertility pits

Fertility pits capture and conserve water in pits that are filled with organic matter, such as old leaves, grass cuttings and manure. Plants with high water requirements, such as bananas, pawpaws and tree tomatoes are grown in and around the pits where they benefit not only from the available moisture, but also the fertility associated with the organic matter that is used. Pits are usually quite large, in the region of 2 metres in diameter and are dug to a depth of approximately 1 metre. The basin is filled with plant material and diversion furrows are often used to direct water into the fertility pit.

2.4.2 Macro-catchment techniques

Macro-catchment techniques, which draw water from a larger area and then concentrate it in the target area, whether a cropland or rangeland, either make use of bunds to harvest and direct flow or make use of techniques aimed at spreading water so that there is opportunity for infiltration. The latter can be achieved through the use of permeable rock dams or water-spreading bunds. Six macro-catchment techniques are discussed below.

Diversion furrows

Diversion furrows direct rainwater from gullies, roads, grasslands or other runoff producing areas either into a storage tank or for productive use in the field. The technique involves the identification of runoff producing areas and the digging of a ditch or furrow to guide the water to its desired destination. The gradient of the furrow is dependent on the erodibility of the soil and shallow gradients should be used where soil is erodible. Diversion furrows are commonly used in conjunction with trench beds.

Permeable rock dams

Permeable rock dams are a floodwater farming technique that slows and spreads the flow of runoff water within watercourses. Low rock structures are placed perpendicular to the watercourse and approximately follow the contour going out of the watercourse. Sediment is deposited when the water velocity is reduced making conditions favourable for plant growth, gradually filling up the valley bottom. This practice is often used in valley bottoms that have become eroded, resulting in the floodwater no longer spreading naturally, which helps with controlling gulley erosion. The main limitation of permeable rock dams is that they are site specific and require considerable amounts of rock and labour.

Homestead ponds

Homestead ponds were observed to be utilised in the collection and storage of rainwater in Thaba Nchu (Free State) and Tyume Valley (Eastern Cape), which were used for livestock watering and crop irrigation. These systems emerged out of a need to maximise available water due to a reduction of size of productive land due to the consolidation and cramping of settlements where limited resources in confined spaced needed to be utilised optimally (Figure 2.8).

Figure 2.8: Example of a pond and channel system for RWH&C

Saaidamme

Saaidamme (literally 'planting dams') were found in the Northern Cape around the town of Clanwilliam. This area is an arid, flat desert landscape with annual rainfall of 100-200 mm, which is highly unreliable. The Saaidamme are related to floodwater irrigation in the Nile River and flood spate systems of Pakistan. The saidamme rely on spate flows from distant mountains between 100 and 150 km away, which is diverted into a series of large, flat basins between 1 ha and 100 ha in size. This is South Africa's largest and most remarkable RWH&C system, estimated to cover 35 000 ha in the arid Northern Cape. The RWH&C system is used mainly for the production of lucerne, which is used for fodder and harvested for seed (Denison and Wotshela, 2009).

Kliplaate and vanggate

Kliplaate and vanggate date back to the nineteenth century in Stilbaai in the Western Cape. Translated from Afrikaans, they mean paved-rock and catch pits, whereby drainage from an adjacent impermeable surface ('paved rock' – in this case calcrete formations) is channelled into an underground tank cistern. The system is used primarily for domestic water supply and watering of livestock (Denison and Wotshela, 2009).

Granite dome harvesting

In the dry Northern Cape, the town of Paulshoek, despite having boreholes and rooftop RWH&C, sometimes suffer from water shortages. A granite dome near the town was adapted to capture rainwater. All loose rocks, soil and vegetation were removed from the dome and cracks and crevices were sealed with cement. Runoff is collected by a small cement wall, half a metre high, concentrates the runoff and channels it to a storage dam. The harvested rainwater is used until finished, which is up to four months, after which other sources of water are used (Denison and Wotshela, 2009).

2.4.3 Rainwater harvesting and conservation in rangelands

Botha et al. (2014) note that as rangeland condition deteriorates, so does water use efficiency and consequently dry matter production also decrease. This is attributed to two factors. Firstly, with improved condition, there is higher basal cover which increases infiltration and reduces runoff, meaning that there is more plant available water. Secondly, climax (decreaser) grass species make more efficient use of water when compared with pioneer (increaser) species. Thus, the efficiency with which rainfall is converted into plant biomass for grazing purposes, without deterioration of the grassland condition, forms the basis for farm sustainability. Animal performance and stocking rates are consequently closely linked to the management and water use efficiency of the grassland. Simply put, grassland in poor condition has a low water productivity, which translates to low livestock water productivity.

Botha et al. (2014) note further that water harvesting for improvement of rangelands is relatively rare and that controlled access by livestock and long-term grazing management are arguably more important than any rainwater harvesting technique that is applied. Furthermore, rainwater harvesting is an intervention of last resort used on severely degraded rangelands because the mechanical disturbance associated with introducing RWH&C can be detrimental to functional grasslands, including those with poor species composition.

2.4.4 Complementary water conservation methods

In addition to the rainwater harvesting practices described above, there are a range of complementary water conservation methods that can be applied to increase water productivity. The main types are listed below.

- **Mulching** involves the placement of material on the soil surface to reduce evaporation, limit germination of weeds, reduce raindrop impact and increase water infiltration.
- **Trench beds** gardening is used widely in South Africa. Originally developed in the 1960s by Robert Mazibuko in the Valley of a Thousand Hills, the system mimics the functioning of wetlands by creating soils which have a high moisture holding capacity, are soft and loamy and have a high water holding capacity.
- **Intercropping and grass fortification** - the inclusion of legumes in the grass mix in RWH&C systems can increase the productivity of fodder.
- **Conservation tillage** describes tillage systems that conserve water and soil while reducing labour and traction requirements. AFDB (2008) notes that conservation tillage applies four main principles: 1) zero or minimum soil turning, 2) permanent soil cover, 3) stubble mulch tillage, and 4) crop selection and rotations (AFDB, 2008).

Text Box 3: Gelesha: An indigenous form of conservation agriculture

Gelesha is considered to be the oldest Southern African recorded practice of soil conservation and water conservation (Denison and Wotshela, 2009). *Gelesha umhlaba* is a Xhosa term referring to the practice of tilling the soil after harvest (either by hoe or plough). The purpose was to break and roughen the soil surface to allow infiltration of water into the soil in preparation for planting in the next season. Another reason for the *Gelesha* practice was that in autumn and early winter, when *Gelesha* was practiced, the oxen used for ploughing were still in good condition, whereas in spring animals would have lost vigour due to a lack of winter nutrition and would not be able to plough as effectively. In addition, prior to the first rains, soils would be very dry and difficult to till. The *Gelesha* system thus allowed for planting immediately after the first rains without significant additional tillage. Thus it was suited to the local socio-cultural parameters, such as oxen having vigour and early planting of seeds. This highlights the need to not only consider the technical elements of RWH&C and to view them in the context of local livelihood strategies.

Figure 2.9: Mulching as a complementary practice to conserve soil moisture

Table 2.2: Broad categories of rainwater harvesting, descriptions and uses (Critchley and Siegert, 1991; AFDB, 2008; Botha et al., 2007; Oweis et al., 2012; Denison et al., 2011)

NAME (S)	MAIN USE	DESCRIPTION	WHERE APPROPRIATE	ADVANTAGES	LIMITATIONS
MICRO-CATCHMENT, ON FARM TECHNIQUES					
Runoff strips					
In-field rainwater harvesting / mechanised basins	Crops	Small basins with production areas with a runoff generating and runoff receiving areas	Dry areas with shallow slopes; inclusion of mulch in the collection area significantly enhances water productivity	Maximises runoff to productive areas through crusting of runoff generating surface.	Works best with mechanisation and requires flat, even topography
Bunds and contour techniques					
Contour bench terraces	Trees and bushes	Bench terraces constructed with a growing area immediately above the terrace and a runoff generating area above that.	Steeper slopes where rainfall is between 200-600 mm per annum	Suited to steep areas	Construction costs and labour requirements for construction and maintenance are high
Contour bunds and ridges / tied contour ridges	Trees, crops and grass	Earth bunds on contour spaced at 5- 10 metres apart with furrow upslope and cross-ties	For crop production in semi-arid areas especially where soil fertile and easy to work	Versatile - can use machinery, animal traction or hand labour and used on a wide variety of slopes More economical than negarims when applied on larger areas of land. Yield of runoff from the short catchment length is extremely efficient, - no runoff loss from the system	Not suitable for uneven terrain. Requires new technique of land preparation and planting, therefore may be problem with acceptance

NAME (S)	MAIN USE	DESCRIPTION	WHERE APPROPRIATE	ADVANTAGES	LIMITATIONS
Contour stone bunds	Crops	Small stone bunds constructed on the contour at spacing of 15-35 metres apart slowing and filtering runoff	Versatile system for crop production in a wide variety of situations; Easily constructed by resource poor farmers	Can be applied quickly and cheaply; important to use a combination of large and small stones	Only possible where abundant loose stone available
Semi-circular and trapezoidal bunds	Crops, Rangelands, Fodder (including trees)	Trapezoidal shaped earth bunds, with tips on the contour line; Staggered formation capturing runoff from external catchment and overflowing around wingtips	Widely suitable (in a variety of designs) for crop production in arid and semi-arid lands; Useful for grass reseeding, fodder or tree planting in degraded rangeland	Used to enclose larger areas often from an external or long-slope catchment, which feed the bunds; Simple design, minimal maintenance, quick and easy for improving rangelands.	Labour intensive and uneven depth of runoff within plot; Limited to low gradients; Cannot be mechanised therefore limited to areas with available hand labour
Fanya juu Terracing	Trees crops in ditches; fodder on bunds	Contour trench with removed earth placed upstream of trench which expand over time	Deeper soils, steeper slopes, higher rainfall	Reliable increases in crop yields	Labour intensive; Unprotected bunds not established to grass are highly susceptible to erosion
Stone terracing	Crops	The use of rocks, stones or other materials (e.g. tyres) to create level cropping land in steeper areas.	Where flat land is limited and best practiced where soil is fertile.	Makes use of land that is usually too steep for farming	Labour intensive and requires maintenance; Risk of damage in floods
Planting pits and basin techniques					

NAME (S)	MAIN USE	DESCRIPTION	WHERE APPROPRIATE	ADVANTAGES	LIMITATIONS
Zai pits (also known as Chololo, Matengo, Ngoro)	Crops	Holes dug with a half-moon barrier downstream to collect and concentrate runoff, often fertilised with mulch to improve infiltration; Often used in conjunction with contour bunds to slow runoff	Flatter slopes in drier areas	Flexible design, easily adapted to local conditions; Help to regenerate soil	Will not work in sandy soils; Subject to waterlogging in wet years
Katumani	Crops and rangelands	Similar to Zai, but a series of interlocking pits, involving pitting and ridging	Rehabilitation of grazing lands and cultivation of crops	Improved fodder production, with good pasture yields, inclusion of legumes advantageous	High labour requirement and requires exclusion of livestock
Ploegvoere	Grazing and degraded lands	Local adaptation of planting pit system, creating numerous small pits across the landscape.	Used at a large scale in areas where grazing land has been degraded.	Mechanisation means that this RWH&C technique can be applied to large areas.	Only suitable for very dry areas with flat slopes.
Negarim basins	Trees and grass	Closed grid of diamond shapes or open-ended "V" s formed by small earth ridges, with infiltration pits	For tree planting in situations where land is uneven only a few trees are planted	Neat, precise and relatively easy to construct. Also act as soil conservation structures	Not easily mechanised therefore limited to small scale; Not easy to cultivate between tree lines
Fertility pits	Trees	Large pits (2 m diameter by 1 m depth), filled with organic matter and planted to plants with high water requirements	Mostly used in homestead gardens	Stores large amount of water	High labour requirement for establishment and limited to small areas

NAME (S)	MAIN USE	DESCRIPTION	WHERE APPROPRIATE	ADVANTAGES	LIMITATIONS
MACRO CATCHMENT (LONG SLOPE CATCHMENT TECHNIQUE)					
Permeable rock dams (Water Spreading)	Crops	Long low rock dams across valleys slowing and spreading floodwater as well as healing gullies	Suitable for situation where gently sloping valleys are becoming gullies and better water spreading is required	NOT IN-FIELD	Very site specific and needs considerable stone as well as provision of transport
Diversion furrows (Channelling)	Crops	Involves the construction of channels which divert runoff into areas of productive use; Often used in association with other micro-catchment techniques	Where runoff generating areas can be used to supplement rainfall falling on micro-catchment systems	Increases water availability in micro-catchment systems	Requires proper design to prevent deposition if slope to shallow and erosion if gradient is too steep; Not suitable for highly erodible soils

2.5 Factors to consider when selecting rainwater harvesting systems

The choice of RWH&C techniques depends on landscape, slope, rainfall and rain pattern, soil type, crop and availability of local material and labour. Consequently, the selection of the appropriate technique depends on the combinations of amount of rainfall and its distribution, soil type and depth, land topography, and local socio-economic factors (Oweis et al., 1999). As a result, the selection and design of RWH&C systems tend to be quite site specific.

The factors affecting the viability of RWH&C and the selection of techniques are discussed below (the information in this section is derived largely from Critchley and Siegert, 1991. Where other authors have been included, these are referenced as such).

2.5.1 Technical considerations

From a soils perspective, the physical, chemical and biological properties of the soil affect how plant yields respond to soil moisture. The characteristics of soils suitable for RWH&C are similar to the soil requirements for irrigation. The following elements are important:

- Depth should be sufficient to store sufficient water for crop growth and not dry out too quickly. Optimal depth is dependent on soil texture. Soils of less than one metre are poorly suited to RWH&C.
- Texture should ideally be loamy (optimal mix of sand, silt and clay) with relatively high organic matter content.
- Structure should allow for good infiltration and sufficient pore spaces to store water. Again loamy soils have optimal infiltration rates and water storage capacity.
- Low soil fertility is often a constraint to crop production. There should be some information on the soils inherent fertility before RWH&C is applied.
- Saline and sodic soils should be avoided.

These parameters represent the ideal or most suitable soil conditions for RWH&C. In reality, rural farmers in South Africa use the land that is available to them, despite the limitations that the soil and climate may present. It is therefore necessary to understand soil characteristics before engaging in RWH&C activities. This will allow mitigation for serious soil limiting factors, such as depth, fertility, texture, etc.

On slopes greater than 5%, RHW&C is generally not recommended as there is uneven distribution of runoff on steeper slopes. Furthermore, large quantities of earthworks are required, which are not economical, particularly in the socio-economic context in which RWH&C is usually promoted.

In terms of rainfall, Botha et al. (2007) suggest that lower and upper rainfall limits for their IRWH technique are 500 mm and 700 mm respectively, while Critchley and Siegert (1991) consider rainfall ranges of 150 mm to 750 mm per annum suitable for RWH&C. Everson et al. (2011), however, found that RWH&C also yielded benefits in higher rainfall areas in KwaZulu-Natal where improvements in crop and livestock systems were demonstrated at rainfall of 800 mm per annum, where water harvesting increased the productivity of rainfall through improved crop production. These various sources show that RWH&C can be practiced, at the least, under rainfall conditions of 150-800 mm per annum.

Rainfall intensity and distribution are also important considerations. RWH&C under short-duration, high intensity rainfall conditions are more likely to yield positive results when compared with long duration, low intensity events. Distribution through the growing season is also an important consideration.

Annual variability of rainfall provides an indication of the likelihood of rainfall exceeding a certain value. This is important in hydrological planning for RWH&C. Design rainfalls and probability of exceedance is a statistical tool used to determine the probability rainfall exceeding a certain threshold. This helps to determine the minimum rainfall required for the proposed RWH&C technique to deliver the required water to the plants in question. For example, a certain area may require 500 mm of rainfall for successful RWH&C. If the probability of exceedance is 50% (i.e. only likely to be exceeded one out of every two years), then RWH&C is not supported based on the rainfall parameter (although other factors may come into play). Conversely if the probability of exceedance is 90% (i.e. likely to be exceeded in nine out of every ten years) then RWH&C is supported based on this parameter (see Critchley and Siegert (1991) for a detailed explanation).

The main cost factor to consider is the quantities of earthworks involved in constructing RWH&C as this directly affects how costly it will be or alternatively how labour intensive it will be under sweat-equity schemes.

In summary, the review of the literature reveals that there are numerous adaptations and modifications of a common theme of contour based interventions for RWH&C. A major limitation in the application of RWH&C in South Africa appears to be that of slope. Most techniques are limited to slopes less than 5%, which reduces RWH&C options available for steeper slopes. Soil depth is also a limiting factor. Considering the topography of South Africa, and in particular the location of many rural communities as a result of past discriminatory settlement patterns (being often on hilly areas with marginal soils), there are constraints placed on the widespread promotion of RWH&C in these areas. However, systems that concentrate rainwater, even on marginal and shallow soils, do have potential to increase and stabilise crop yields, particularly when used in conjunction with other soil conservation practices. It is also necessary that RWH&C options involving steeper slopes be identified and investigated.

2.5.2 Social and cultural considerations

Oweis et al. (1999) note that well established water harvesting systems are characterised by flexibility and endurance. This flexibility is demonstrated by their easy integration with other resource use systems and widespread adoption of the practice by diverse cultural groups in different parts of the world. Endurance is shown by their antiquity and their capacity to persist in the face of abrupt changes in the social order and were therefore appropriately simple and within the capabilities of individual households or small communities. Such enduring systems have been developed though empirical research and testing over many years by farmers to become socially and culturally acceptable and robust systems. The success of such enduring systems highlights the need to ensure that local social and cultural priorities are considered when introducing ‘new’ technologies.

Due consideration must be given to social and cultural aspects in the area of concern as these will affect the success or failure of the technique implemented (Botha et al., 2007). In arid and semi-arid Africa, rural populations with subsistence livelihoods have over thousands of years set livelihood priorities for survival. Until all higher priorities have been satisfied, no lower priority activities can be effectively undertaken (Critchley and Siegert, 1991). In addition, the following factors should also be considered when introducing RWH&C systems:

- ***Participation***: Active involvement of beneficiaries in the development of the project and identification and selection or RWH&C is necessary for success. On-going participation by farmers in monitoring and record keeping further creates a sense of ownership. Local knowledge is also critical – farmers understand local constraints and opportunities and can inform the design and the modification of designs of RWH&C systems.
- ***Adoption***: Only wide adoption by many participants will result in scales of adoption being large enough for significant areas of land to be developed for RWH&C and the associated positive socio-economic impacts.
- ***Area differences***: A successful system in one area cannot necessarily be successfully applied in another area. This may be due to different biophysical factors (e.g., rainfall, soils), social systems or the functioning of local institutions.
- ***Gender and equity***: Gender norms and values should be borne in mind during project design, as should local power relations. It is of limited value if RWH&C interventions benefit only the more prosperous members of a given community.
- ***Land tenure***: Ownership and security of access to land, particularly in communally owned lands where much land is a common property resource, can influence how land is used and managed. Without secure access or tenure, a farmer is unlikely to invest in improvements to land, such as RWH&C.

It is important to understand what farmers one is working with when introducing RWH&C techniques. This leads us to a discussion of smallholder farming typologies.

Smallholder farming typologies

The definition of smallholder farming systems varies between countries and agro-ecological zones (Pienaar, 2013). Numerous terms are associated with the smallholder concept namely: "small scale", "subsistence", “resource-poor", "low-income", "low-input" and "small" (Powell et al., 2004; Pienaar, 2013). Machingura (2007) defines smallholder farmers as farm households which have access to land in which family are the primary source of labour to ensure agricultural production for subsistence or market sale. Additionally, smallholder farming systems can be defined on the basis of land and livestock holdings, where cropping generally takes place on less than 2 hectares and households only own a few head of livestock (World Bank, 2003; cited in Pienaar, 2013; Salami et al., 2010). They can also be defined as households operating on small tracts of land with limited labour (Havemann and Muccione, 2011). Production from these systems tends to be on a subsistence scale for household consumption produced from homestead gardens, demarcated fields or communal rangelands (Aliber and Hart, 2009).

In South Africa, many smallholder farming systems are characterised by dryland agriculture due to the arid and semi-arid nature of the country (Vetter, 2009; Stewart et al., 2006). In essence, the smallholder farming systems in these water-stressed environments are reliant on rainfed agriculture, making them vulnerable to climatic variables (Stewart et al., 2006; Van Averbeke and Khosa, 2007; Thornton and Herrero, 2015).

Smallholder systems in developing countries are important to employment, livelihoods and political stability, and should not be treated as a small, insignificant adjusting sector of a market economy (Delgado, 1999; Russelle et al., 2007). Smallholder agriculture is the backbone of rural livelihoods and contributes to economies in many regions (Louw et al., 2008). However, numerous challenges need to be overcome and there still exists a need to promote the growth of smallholder farming systems within developing countries (Delgado, 1999). Livestock are important components in the livelihoods of people living in these smallholder farming systems.

For the purposes of this report, and acknowledging the complexity of categorising smallholder farming systems into defined parameters, the definitions provided by Christen and Andersen (2013) are used in this report.

- **Non-commercial smallholders** - generally considered subsistence farmers. Among the world's poorest households, they farm not as a vocation or strategic business choice, but to contribute to their own sustenance and survival. Agricultural production is concentrated in staple crops (e.g. cereals, roots and tubers, pulses) and could include small livestock (e.g. hens, goats, pigs). Access to land, technology, education, markets, and information about weather or production methods is very limited. Very few purchased inputs and little mechanisation are used (if any), and the household is highly vulnerable to income and other shocks. Outputs are relatively low and consumed largely by the household. They are generally buyers of food (supplementing their own production) and sellers of labour, which limits their ability to produce, and they may endure periods of food deficits throughout the year. Any irregular, small amounts of surplus would be sold in an informal, local market. Non-commercial smallholder households are not connected to a structured value chain of any kind. They are largely limited to informal financial mechanisms and simple tools, such as local savings and loan groups, to meet their relatively basic financial service needs.
- **Commercial smallholders in loose value chains** - are still considered very poor, but tend to be somewhat less so than the non-commercial smallholder segment. Their crop mix

usually focuses on staple crops and could also include some higher-value crops (e.g., vegetables, sugar, tea, coffee, oilseeds, fibres and energy crops). They have access to somewhat more land than the first segment, though they still have limited access to inputs, financial services, and information about weather, markets, and prices and tend to rely on unimproved seeds and traditional production methods. Commercial smallholders in loose value chains generate some level of surplus to sell, usually in informal local or regional markets. These households have access to a wider range of financial services than non-commercial smallholders and may be looking for opportunities to further diversify their assets and sources of income.

- **Commercial smallholders in tight value chains** - are generally less poor and more resilient than the other two segments and take a more business-like approach to farming. A sizeable portion of their agricultural income may be derived from higher-value specialty crops, though they are also likely to grow some staple crops as well. They tend to manage at least two hectares of land (subject to important regional differences) and, due to their place in relatively more structured value chains, have access to buyer-provided bundles of improved seeds, inputs, agricultural and weather information, finance, and secure markets and prices. Commercial smallholders in tight value chains have the capacity to generate reliable, high-quality outputs that are sold on a contract basis through relatively highly organised value chains. Staple crops may be sold more informally through local and regional markets. As relatively larger producers, they may hire people to support some of their agricultural activities, including members of the two other segments. They are likely to demand and use a wider range of financial services from both formal and informal financial service providers than the other two segments.

This research project focused on farmers in the category "non-commercial smallholders".

Factors influencing adoption of RWH&C

There are many challenges to developing rainfed agriculture. Rockstrom et al. (2007) noted that in rain-fed situations, landholdings are often small and marginal for agriculture. These areas have poor infrastructure because investment has historically focussed on high potential irrigated areas. In many rural areas, local institutions engaged in supporting and providing extension services to agriculture have limited capacity to support and promote RWH&C and management. Limited information on the options available for water management, compounded by social and economic constraints to adoption, a lack of an enabling environment, infrastructure, backup services and poor market linkages further limit successful demonstration and adoption.

Rockstrom et al. (2007) also pointed out that the temporal and spatial variability of climate, especially rainfall, is a constraint to yield improvements. The high risk of water related yield loss means that farmers are averse to taking risks with other investment decisions in their production systems, for example in labour, improved seeds and other inputs such as fertiliser.

Reducing the risk of rainfall variability can encourage farmers to invest in other aspects of production and be in a better position to respond to new market opportunities.

At a local level, transferring new technologies to rural communities is notoriously difficult and practitioners need to proceed with care in the approach that is being taken (van Averbeke, 2004). Many water harvesting and conservation technologies that have shown great potential for decreasing poverty and food insecurity have suffered from low adoption rates in rural communities. A household's ability to adopt different crop management options depends on a range of socio-economic and biophysical factors, which, if not considered, will result in households rejecting, or at least not considering, innovative technologies (Botha et al., 2007). These issues can be addressed by investment in schooling and education, improving health and placing people at the centre of development (Backeberg, 2009). This creates the development space in which new technologies can be explored without having to be concerned about major social constraints to development.

In particular, the interface between technology and local institutions needs to be considered when engaging with rural communities. While RWH&C techniques have the potential to contribute to food security, poverty alleviation and job creation, the sustainable adoption and management of the systems will be determined to a large extent by institutions that exist or are lacking in the communities (e.g. resource tenure and property rights systems). Rule changes, and by extension technology changes, intended to change a particular performance may fail to produce the expected results because the institutional structures are informed by cultural norms and values rather than formal rules (Botha et al., 2007). Thus, the need to assess the state and functioning of local institutions is necessary to enhance uptake and long term adoption of RWH&C systems.

Botha et al. (2007) suggest that to address the issue of low adoption in rural communities, five pillars of sustainability should be addressed. Sustainability involves the appropriate use of crop systems, and agricultural inputs supporting those activities, that maintain economic and social viability while preserving the productivity of land. These should result in an improvement in agronomic productivity, reduction in production risk, conservation of the natural resource base, economic viability and social acceptability. These elements should be demonstrated at a pilot scale prior to significant interventions in outscaling to ensure that local contexts and constraints can be identified and addressed prior to significant investment in outscaling. Botha et al. (2007) highlight the important motivators and demotivators that need to be considered and addressed when engaging in the introduction of new technologies in rural communities in South Africa (Table 2.3).

Table 2.3: Motivators and demotivators to the introduction of RWH&C (Botha et al., 2007)

Motivators	Demotivators
Create excitement	Project overload
Good and supportive leadership	Cultural issues and constraints
Established organisations and structures	Local / village politics
Collective action and communal approach	Lack of mutual respect
Good communication and coordination	Drought
Good or improving yields	Negative and unsupporting leadership
Regular meetings	Confusion
Festivals and awareness days	Cliques and groups
Clear and agreed action plans	Dysfunctional organisations and structures
Maintenance	Unfulfilled promises
Income from RWH&C	Dependency syndrome
Open communication channels	Lack of tools
Simplicity of technique	

At provincial and national spheres of government and governance, investments and policies in support of rainfed agriculture can also enhance improvements in rainfed agricultural production. Rockstrom et al. (2007) note that in the last 50 years, the focus has been on crop research, soil conservation and, to a lesser extent, in-situ water conservation (described as maximising rainfall infiltration), whereas there should be a holistic focus on water resource management in rainfed agriculture. Farmers also lack skills and knowledge on how to effectively utilise RWH&C techniques and often do not have finances to purchase inputs (IWMI, 2011)

Furthermore, policies have focussed on the 'dry' parts of dryland agriculture, rather than the 'wet' parts of dryland agriculture. While knowledge for improved rainwater management and productivity exists to develop these innovations, governance, policies, institutions, practices and technologies to support improved water management by dryland farmers has been very limited (Rockstrom et al., 2007). A key reason for this is the lack of support from government to out-scale these practices (IWMI, 2011). This may be due to a perception among administration and technical staff in ministries and local authorities in Africa that RWH&C is technologically backwards and is associated with small NGO initiatives and household application, rather than for inclusion at national level policy (AFDB, 2008).

The AFDB (2008) notes that an integrated approach to water management, which considers social, institutional and environmental considerations, rather than a simple technological approach creates the opportunity for balanced interventions that that address the socio-economic realities on the ground and is likely to enhance shot term uptake and long-term sustainability of RWH&C interventions. The following national level recommendations are made for enhancing the use and application of RWH&C:

- National water policies should recognise rainwater as the third source of water that should be managed and developed.
- Development of water should be decentralised and communities should be empowered to select the best option depending on the demand.
- Water legislations should minimise conflicts among different policies for water development.
- Water legislation should reflect the country policies for water resources and development and should not contradict each other.
- National water resource policies should be consistent.

2.6 Water productivity conceptual frameworks

Water productivity may be defined as: "The ratio of the net benefits from crop, forestry, fishery, livestock, and mixed agricultural systems to the amount of water required to produce those benefits". In its broadest sense it reflects the objectives of producing more food, income, livelihoods, and ecological benefits at less social and environmental cost per unit of water used, where water use means either water delivered to a use or depleted by a use. Put simply, it means "growing more food or gaining more benefits with less water" (Molden et al., 2007; Molden et al., 2010; Peden et al., 2007). Further definitions provided by Molden et al. (2007) in relation to water use productivity are:

- **Physical water productivity**: The ratio of the mass of agricultural output to the amount of water used (similar to water use efficiency).
- **Economic water productivity**: The value derived per unit of water used – this can refer to a direct financial (income) value or intrinsic values, such as a contribution to supporting livelihoods, ecological benefits and cultural significance.

Water productivity can also specifically describe productivity either for crop production or livestock production systems. While there has been significant research on crop water productivity, building on research that measured crop water use efficiency, research into livestock water productivity is relatively new. Increasing water productivity for crop and livestock systems is particularly relevant where water resources are scarce.

Molden et al. (2007) note that there is significant scope for improving physical water productivity and that many farmers in developing countries could increase water use productivity by adopting proven agronomic and water management techniques, including soil fertility management, rainwater harvesting and soil water conservation. They also caution that adoption of techniques to improve water productivity requires an enabling environment that aligns the incentives of producers, resource managers and society to facilitate uptake of practices and techniques. In this section two major themes are considered – livestock water productivity and crop water productivity. The final section considers the linkages between crop and livestock water productivity.

2.6.1 Livestock water productivity

The keeping of livestock is an important element of agricultural water use in sub-Saharan Africa. Livestock is estimated to contribute 25% to the gross value of production in Southern Africa. In sub-Saharan Africa livestock grazing accounts for 37% of the land area, and mixed rainfed crop-livestock systems account for 25% of the land area, supporting the livelihoods of approximately 80% of the population (Descheemaeker et al., 2010).

Livestock convert water resources into high-value goods and services (Descheemaeker et al., 2010). Globally, livestock account for 20% of agricultural evapotranspiration and this value is expected to rise, given the increasing consumption of animal products. With increasing demand for animal products and a concomitant increase in water scarcity, it is necessary to increase livestock production without using more water (Molden et al., 2007; Descheemaeker et al., 2010).

Livestock water productivity (LWP) is defined as the ratio of the sum of the net benefits derived from livestock compared to the volume of water depleted (i.e. used to produce these benefits) (Peden et al., 2008; Peden et al., 2011). The concept of LWP was introduced by Peden et al., (2007) to investigate and find ways to increase livestock production, but simultaneously reduce the water utilised per unit output (Amede et al., 2009). Much water is depleted worldwide for livestock production which cannot be used again (Peden et al., 2011). A framework is proposed by Descheemaeker et al. (2010a) for smallholder mixed crop-livestock systems which investigates interventions that can improve LWP. These are classified into technical strategies, supportive institutions, and enabling policies (Amede et al., 2009). The technical interventions can be classified into three categories namely feed, water and animal management (Peden et al., 2007; Descheemaeker et al., 2009; Descheemaeker et al., 2010a). Supportive institutions are rules which govern society and inform decision making (Arellano et al., 2011). They can be classified as the rules which monitor the technical interventions. The policy environment is there to support technical interventions and institutional structures that are important for the success of LWP (Amede et al., 2009). It is of no use to implement various management strategies (related to water, soil or vegetation) without creating supporting institutional or policy changes that manage and promote the success these interventions (Descheemaeker et al., 2009; Descheemaeker et al., 2011). It is thus important to adopt a holistic approach which integrates the various interventions to efficiently promote LWP (Descheemaeker et al., 2009; Amede et al., 2009; Descheemaeker et al., 2011, Peden et al., 2011).

The physical water productivity of animal products derives primarily from the water required to produce the food that animals consume. The drinking water requirements of livestock are negligible in comparison (Molden et al., 2007). Access to drinking water obviously plays an important role in feed conversion and animal health and thus livestock do require access to sufficient drinking water and this cannot be ignored. Drinking water requirements range from

20-50 litres per day, while water depletion from transpiration through feed and fodder are estimated to be 50-100 times the amount required for drinking (Meissner, Undated; Descheemaeker et al., 2010).

To better understand livestock water productivity, Descheemaeker et al. (2010) have developed a conceptual framework for assessing livestock water productivity (Figure 2.10) that considers both livestock production elements as well as hydrological elements. The green area represents factors which influence animal productivity and the blue areas represent the inflows and outflows of water through the system in supporting livestock production.

Water flows into the system through precipitation, surface water and groundwater and is used to produce biomass for animal feed, water for drinking and other elements that contribute to animal health (e.g. use in dip tanks). Water outputs occur through evapotranspiration, contaminated and degraded water, discharge and percolation. Livestock outputs contribute to livelihoods and ecosystem services. The extent to which the system is properly managed, considering livestock outputs, water for other users and environmental considerations, determines the extent to which the system contributes to or degrades environmental services.

There is significant scope to improve physical and economic water productivity in livestock systems through improving feed sources and feeding strategies, improving the quality of produce (e.g. milk, meat), greater integration with crop production systems, recognising services and cultural values provided by livestock and conserving water resources to lessen the amount of water required for fodder production (Molden et al., 2007; Meissner, Undated; Descheemaeker et al., 2010).

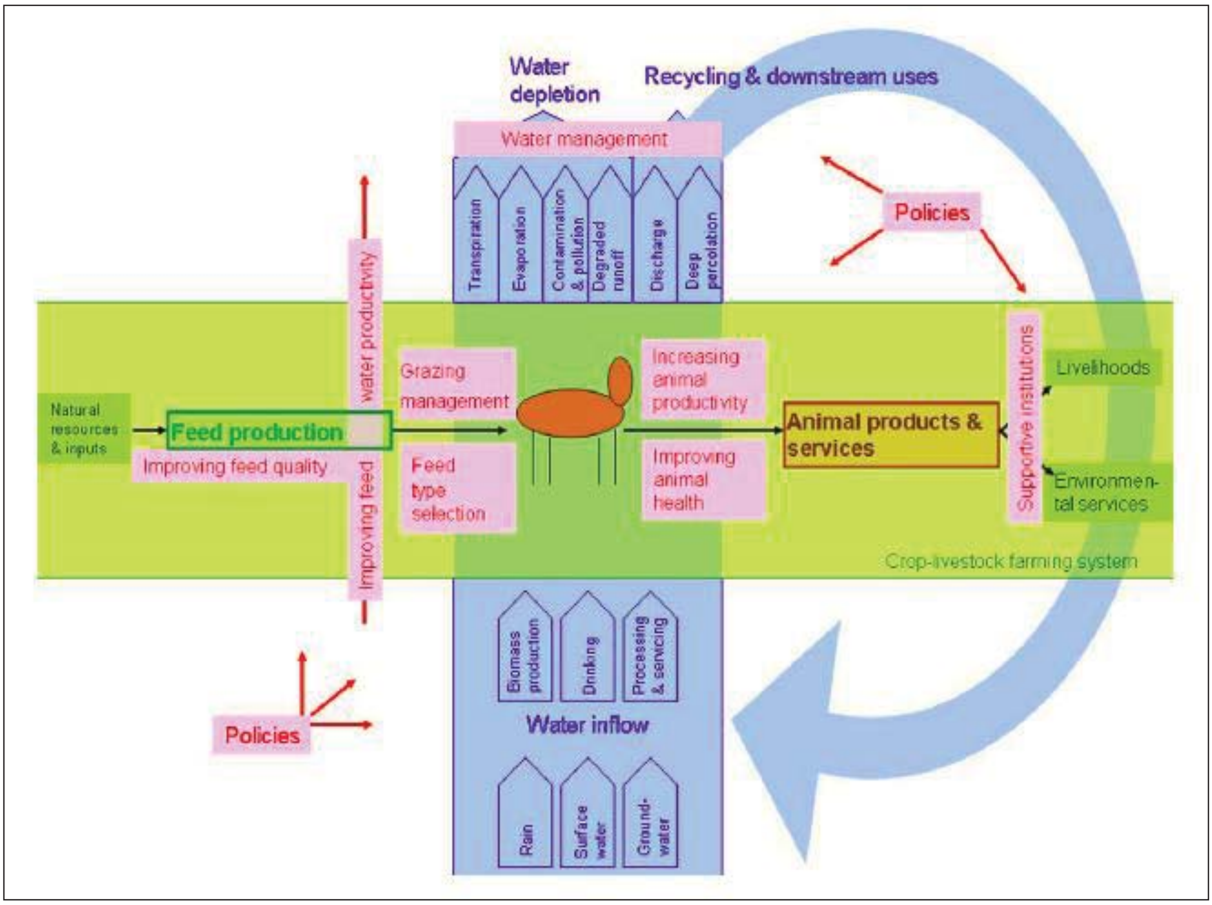


Figure 2.10: A conceptual framework for assessing Livestock Water Productivity (Descheemaeker et al., 2010)

In communal rangelands in South Africa, there is generally low offtake, partly due to the cultural and social value of livestock, but also due to low reproductive rates, high mortality and unfavourable herd/flock composition. Meissner (Undated) compared the productivity of commercial, emerging and communally farmed livestock, which is shown in Table 2.4.

Table 2.4: Comparison of calving, mortality and herd composition in South Africa (Meissner, Undated)

Production statistic	Commercial farming	Emerging farming	Communal farming
Calving Percentage	62%	48%	35%
Mortality	5.8%	5.5%	35.4%
Percentage adult females	52%	49%	25%

The percentages given for commercial farming enterprises can be considered to be low by international commercial standards. For example, in Australia, calving percentage is 76% for beef and 79% for dairy, while in Botswana it is 69-82% (ABS, 2012; Mukasa-Mugerwa, 1989). The values for communal farming systems are considerably lower, which highlights that gains in productivity can be achieved through relatively low cost and simple interventions, such as improved animal husbandry and increased production of fodder for livestock. Meissner (Undated) notes that in a commercial system producing weaners for feedlots, increasing weaning percentage from 60% to 80% can result in a reduction of 20% in water use per kg of meat produced. Similarly, if livestock farmers on communal rangeland systems improve reproductive and weaning rate, biological efficiency will increase, resulting in a reduced water footprint and increased water productivity. Often, livestock water use can be disproportionally high when compared with that of agricultural crops, however, it needs to be borne in mind that livestock often derive nutrition from non-arable land and from crop residues that cannot be used for human consumption. Furthermore, in rural smallholder systems, livestock often provide additional benefits, such as transport, ploughing, fertiliser (manure), as well as reducing vulnerability to food shortages and climate shocks and diversification of livelihoods.

Possible interventions to improve livestock water use productivity

Based on the conceptual framework developed by Descheermaeker et al. (2010), a range of strategies for increasing LWP are identified. The analysis focuses on dryland interventions that produce biomass from rangelands and crop residues as these are of relevance to this research project.

<u>Feed management</u>

The quality and quantity of feed available is an important factor contributing to livestock production. Water is depleted in the production of feed and therefore is relevant to water use productivity. Three categories for feed management are identified, namely feed type selection, feed quality and feed water productivity.

Feed type selection is limited to graze and browse production in rangelands and the availability of crop residues for livestock. The following interventions are identified:

- Crop residues, which do not consume additional water and consequently contribute positively to livestock water productivity, can be used for livestock feeding. This could include the introduction of dual purpose species, intercropping with legumes, green manuring and the selection of cultivars that produce more nutritious residues. The palatability and nutritional value of residues can also be improved through the addition of urea based products
- Rangelands contribute an important part of feed for livestock and are often located on land unsuitable for crop production. However, if rangeland resources are degraded, the plant composition changes towards less palatable and less productive species and degradation also results in runoff and erosion, which further decreases productivity. Interventions to increase water infiltration and control livestock grazing can potentially be applied in this situation.
- Introduction of robust and fast-growing species (e.g. Napier Fodder - *Pennisetum purpureum*) on the boundaries of croplands and in eroded gullies as well as the introduction of fodder trees can improve feed quality and quantity.

There has been substantial research into improving crop water productivity - any interventions in improving crop water productivity will increase livestock water productivity through the availability of crop residues. Consequently RWH&C interventions in croplands will contribute to increased LWP.

Grazing management

Productivity of rangelands can be improved through grazing management that includes appropriate stocking densities and herd composition. Grazing management can positively influence ground cover, net primary production and species composition. Another option to reduce pressure on rangelands is through the introduction of zero grazing systems (i.e. 'cut and carry' systems). Interventions to improve grazing management in common property resource systems require strong institutions and organisations.

Water management

Water conservation refers to practices that limit unproductive water losses through runoff, evaporation and deep percolation. This increases water use efficiency and overall productivity. Soil and water conservation measures include physical structures (including RWH&C) and vegetation management practices. In croplands, the inclusion of cover crops and intercropping generally reduce the amount of unproductive water losses through improved infiltration and a higher amount of transpiration when compared with evaporation, and increase the biomass available for livestock.

Livestock that need to travel long distances to obtain drinking water expend significant energy. Providing access to water nearby to grazing areas reduces energy wasted on seeking out the relatively small amount of water necessary for meeting an animal's physiological water requirements.

Animal Management

Animal productivity in sub-Saharan Africa is characterised by low growth and calving rates. This is as a result of genetic selection of animals that are selected more for their ability to adapt to harsh environmental conditions and disease resistance than for their ability to be productive. This means that there is scope for genetic improvement of livestock for improved water productivity. Breeding interventions are beyond the scope of this research project and it is questionable whether breeding for increased productivity at the expense of hardiness and disease resistance is advisable for rural smallholder farming systems that focus on maximising numbers rather than maximising off take.

Animal health and productivity are also closely linked. High animal mortality can be attributed to a number of interrelated factors, for example, drought and high stocking rates resulting in decreased animal vigour and susceptibility to disease. Stressed and diseased animals are less productive as their feed and water consumption does not produce growth or the delivery of products (e.g. meat, milk, offspring, and traction). Thus, investments in improved animal husbandry can yield positive results for LWP.

How are livestock productively used in rural smallholder settings in South Africa?

Livestock keeping in poor communities reflects the resource constraints that they deal with as well as the various reasons for livestock, which according to Meissner (undated) include:

- **Food security**: A regular supply of nutrient-rich livestock-based supplements to plant-based staple diets is critical. In some systems, also in South Africa, slaughtering livestock for meat is infrequent and only done when animals are sick or old, or when required for ceremonies and hospitality.
- **Income generation**: Owners may produce for the market but in many cases, sales are on an ad hoc basis to meet urgent needs for cash.
- **Manure and fertiliser**: Livestock waste is often used to maintain soil fertility and therefore contributes to better crop production.
- **Draught power**: Cattle and donkeys are used to plough and to transport commodities.
- **Financial instruments**: Where rural farmers do not have access to credit and banking facilities, livestock offer an alternative for accumulating capital, and as a hedge against inflation. Livestock can also be used for urgent cash or as a form of insurance, which can be sold to provide for the family when the owner dies.
- **Building social status**: Many rural societies place great value on livestock as an indicator of social importance. Livestock is also exchanged as lobola.

This highlights the multiple uses and contributions of livestock to local livelihoods and the reasons for livestock keeping need to be borne in mind when considering livestock water use productivity.

2.6.2 Crop water productivity

Bouman (2007) notes that in most field conditions transpiration and evapotranspiration are not measured and that a practical method for assessing water productivity is through water inflows rather than through water outflows. Thus water productivity can be defined as the ratio of economic biomass over total amount of water received by irrigation and rainfall (in the case of this research project, only rainfall). Improvements in water productivity are achieved through reducing non-productive outflows from the field, such as runoff, evaporation, seepage and percolation.

As with LWP, crop water productivity (CWP) refers to the net benefits provided from the production of the crop per unit of water depleted. Principles for biomass production in crop and livestock systems are similar however, in cropping systems the focus is on the portion of the crop that is harvestable by people for food or income, rather than biomass production. Water for crop production is delivered to the soil primarily through rainfall and irrigation. Water is depleted through transpiration and evaporation (i.e. evapotranspiration), runoff from the soil surface and drainage into the soil profile or groundwater, beyond the reach of plants. For any given crop, there is a well-established linear relationship between plant biomass production and transpiration (Molden et al., 2010). Thus, feeding more people will require more water to be transpired (i.e. the component of water use that is productive in terms of crop growth and yield). Because the processes of evaporation and transpiration are difficult to measure separately in the field, evapotranspiration is the commonly used concept and ultimately, the extent of agriculture is limited by the available water that can be depleted by evapotranspiration (Molden et al., 2007; Bouman 2007).

Perry (2007) notes that 'water use' is often not clearly defined and that consumptive and non-consumptive use of water from a cropping perspective is often not clearly understood by some scientists and practitioners. This is further confounded by the different scale at which hydrologists (catchment / basin) and irrigation engineers (field / farm / irrigation scheme) study water, resulting in different accounting systems for water use. Consequently, Perry (2007) provides the following definitions, specifically:

1. The consumed fraction (evaporation and transpiration) comprising:
    a. Beneficial consumption: Water evaporated or transpired for the intended purpose – for example, transpiration of water through a crop to generate yield.
    b. Non-beneficial consumption: Water evaporated or transpired for purposes other than the intended use – for example evaporation from the soil surface or transpiration by weeds.
2. Non-consumed fraction, comprising:
    a. Recoverable fraction: water that can be captured and reused – for example, flows to drains that return to the river system and percolation from fields to aquifers; return flows from sewage systems.
    b. Non-recoverable fraction: water that is lost to further use – for example, flows to saline groundwater sinks, deep aquifers that are not economically exploitable, or flows to the sea.

Bouman (2007) provides a conceptual framework for evaluating water productivity that can express yield as a function of water that is transpired by the crop, as follows.

$$Ya = WP_T \, X \, ETa$$

where:

Ya = *amount of produce (kg)*

WP_T = *crop produced per unit water transpired* $(kg.m^{-3})$

ETa = *amount of water transpired by the crop* (m^3)

Thus, water productivity can be written as

$$WP_T = Ya/ETa$$

And produce is the product of the harvest index and total above ground biomass.

$$WP_T = HI \, X \, B/ETa$$

Where

HI = Harvest index of the crop (kg produce per kg biomass and can range from 0-1)

B = Biomass of the crop (kg)

The fraction B/ETa is known as transpiration efficiency.

Based on these calculations, three strategies for improving water productivity are identified:

1. Increase transpiration efficiency. This is a reflection of the amount of biomass produced per unit of water transpired (*B/ETa*).
2. Increase harvest index. This is a ratio of the amount of biomass produced in relation to the mass of the crop that is productively used. In the case of dual purpose crops, the HI can be a weighted index reflecting the relative contributions of the crop to harvestable yield and to fodder.
3. Increase the total amount of water transpired.

Mabhaudi et al. (2016) note that water for agriculture and crop productivity play an important role in delivering food and nutrition security, particularly in sub-Saharan Africa (SSA), where 70% of the population relies on agriculture, of which 95% is rainfed. It is highlighted that a transdisciplinary approach that includes agricultural scientists, nutritionists and dieticians is required. This would allow recommendations to be made for farmers to achieve the most optimal biomass *and* nutrition per unit of water consumed – namely nutritional water productivity (NWP). NWP is defined as nutritional value per unit of water consumed and provides a more meaningful analysis of food production in the context of malnutrition and poverty. Mabhaudi et al. (2016) note that increasing agricultural production without increasing water use will contribute to improving food and nutrition security without compromising scarce water resources. In light of nutrition considerations, NWP is defined as:

NWP = (Ya/ETa) X NP

Where:

NWP is the nutritional water productivity (nutrition per m^3 of evapotranspired water)

Ya is the actual harvested yield ($kg.ha^{-1}$)

ETa is the actual evapotranspiration ($m^3.ha^{-1}$)

This equation thus contains the water productivity (Ya/ETa) calculation and is multiplied by a nutritional productivity factor, defined through empirical research, based on the particular nutritional element on which the research is focussed (e.g. kg protein per $m^{-3}ha^{-1}$).

Rainwater harvesting and conservation systems should partition rainfall in favour of productive and nutritional water use in crop and rangelands. It can therefore be expected that greater production should be achieved from any given amount of rainfall where RWH&C is applied, when compared with conventional production systems.

Plant breeding has contributed significantly to increasing the production of harvestable material over the last 40 years, but that the rate of increase has slowed as plant physiological limits are being reached. Further increases in food production in productive areas will require proportionate increases in transpired water. While there is a linear relationship between biomass and transpiration, there is significant variability in yield (the productive / useable portion of a crop) relative to transpiration. This is due to differences in climate conditions, water stress, cultivars, pests and disease, soil nutrient status and other management and agronomic factors. Consequently, where yields are low in relation to a plants' yield potential due to sub-optimal management practices or environmental conditions, there is scope for increased crop water productivity (Molden et al., 2007; Molden et al., 2010). Management practices that (1) increase the productive amount of rain falling on a field and available for crop production and (2) increase yield relative to evapotranspiration (ET) by reducing evaporation and increasing the proportion of water that is transpired are a key focus of water productivity in cropping systems.

Crop water productivity can be increased in a number of ways (Molden et al.,2007; Molden et al., 2010; Oweis et al., 1999):

- Physical strategies:
    - Improving soil fertility – for arid and semi-arid areas, particularly Sub-Saharan Africa, fertiliser use is low and nutrient limitations often constrain yields more than the availability of water.
    - Reducing evaporation, while increasing transpiration also enhances water productivity. Practices such as mulching, ploughing or breeding for fast leaf expansion to shade the ground rapidly to reduce evaporation are some practices that could work.
    - Water harvesting – up to 90% of rainfall evaporates back into the atmosphere. Water harvesting can increase the beneficial water available for transpiration by 20% to 50%.
    - Supplemental irrigation at critical phases in the crop production cycle can significantly enhance crop water productivity by preventing crop failure or significant yield reductions.
    - Management interventions such as selection of the most appropriate crop type and variety and timing of planting suited to local conditions to improve yield and water productivity.
    - Using international trade to increase global water productivity – involves growing crops where water productivity is high and trading with low water productivity.
- Economic strategies for increasing the net value of water used
    - Increasing yield.
    - Changing from low to high value crops.

- Re-allocating water from low to higher valued uses.
- Lowering the costs of inputs.
- Increasing health benefits and the value of ecological services of agriculture.
- Decreasing social, health, and environmental costs.
- Obtaining multiple benefits per unit of water.
- Achieving more welfare per unit of water.

In identifying interventions to increase the productivity or value of water use, a wide range of factors need to be considered. These factors should look beyond the direct costs and benefits for a given production system. Principles such as contributions to ecosystem services and livelihoods need to also be borne in mind.

2.6.3 Linkages between crop and livestock systems

Mixed crop and livestock systems have a high degree of complementarity in terms of resource use and optimising crop and livestock interactions to increase productivity and income generation, while also enhancing system resilience (Descheemaeker et al., 2010). Such integration also improves water productivity in the whole farming system.

Farming systems that involve combination of crops and livestock produce 50% of the world's cereals and produce most of the staples consumed by poor people (41% of maize, 86% of rice, 66% of sorghum and 74% of millet production) as well as 75% of the milk and 60% of the meat in the developing world (Thornton and Herrero, 2010). Potential interactions between the crop and livestock components can be strengthened through improved integration, to improve the productivity of the overall system (Figure 2.11).

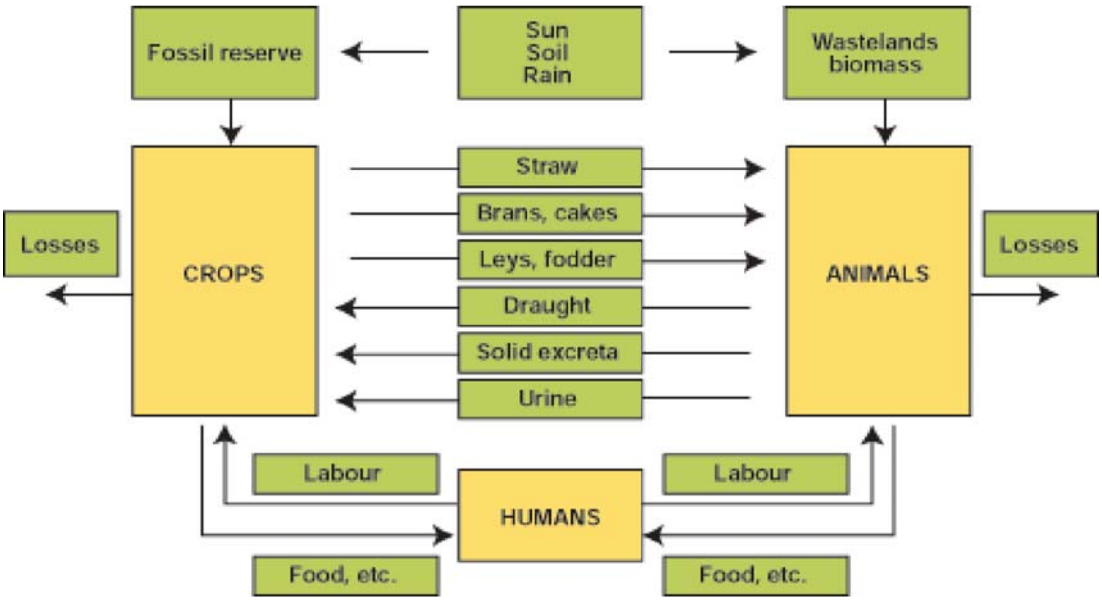


Figure 2.11: The outline of different resource flows in mixed crop-livestock systems (FAO, 2001)

In rural parts of South Africa, crop-based feed sources for livestock mainly refer to crop residues (such as maize stover that remains after harvest of the grain), but could also include ley crops grown to improve soil fertility and structure.

Interactions that benefit the crop component include the supply of manure as an alternative to inorganic fertilisers. Manure (solid excreta in Figure 2.11) improves soil structure by adding organic matter, while also maintaining soil fertility (Rota and Sperandini, 2010). Given that farmers regularly complain about that declining fertility of soils, and a lack of response to inorganic fertiliser (Cousins, 2011), farmers would benefit from increased usage of manure. The supply of draught power mainly with donkeys and cattle is used to transport goods and till fields (FAO, 2001), which also benefits the cropping component of the system.

Market participation is another factor that is another interaction that is encountered in crop-livestock systems. In other parts of Africa, for example, studies have found that if households have excess cash from sale of crops it is sometimes used to purchase livestock and build up the asset base (Jaleta and Gebremedhin, 2010).

It is therefore necessary to recognise the value of the rangelands and cropping lands as an integrated system. Part of the research focus of this project is to understand how well these systems are integrated as well as the benefits and synergies as well as the drawbacks and conflicts related to the integration of crop and livestock systems and how this influences productivity.

2.7 Dynamics influencing access to and use of communal croplands and rangelands

This section considers the role of institutions, land tenure systems and related factors that influence access to and use of communal crop and rangelands.

2.7.1 Institutions and rule making

North (1992) notes that economic activity does not occur in an institution-free environment and that institutions play an important role in economic transactions. Institutions are a reflection of the mental models we use to interpret (simplify) the complex world around us. These mental models are largely a result of values and norms associated with a given society, but are also obtained through individual experiences within a particular environment. In the process of simplifying the complexity, constraints on human interactions are created in relation to exchange of information, ideas, concepts, transactions, etc.. These constraints represent the institutions (or 'rules of the game'), and represent the boundaries of the system in which a certain group of people interact. Consequently, institutions play an important role in governing how human exchange occurs and determine the cost of transacting - "when it is costly to transact, institutions and particularly property rights are crucial determinants of the efficiency of markets" (North, 1992).

North (1992) provides the following differentiation between institutions and organisations:

"Institutions are the rules of the game of a society or more formally are the humanly-devised constraints that structure human interaction. They are composed of formal rules (statute law, common law, regulations), informal constraints (conventions, norms of behaviour, and self-imposed codes of conduct), and the enforcement characteristics of both.

Organisations are the players: groups of individuals bound by a common purpose to achieve objectives. They include political bodies (political parties, municipalities a regulatory agency, traditional authorities); economic bodies (firms, trade unions, family farms, cooperatives); social bodies (churches, clubs, athletic associations); and educational bodies (schools, colleges, vocational training centres)" (North, 1992).

While institutions do change over time, this process is generally slow as the interpretation of the system which informs the rules is usually based on deeply held cultural norms and values. Thus, while formal rules change rapidly (e.g. through the introduction of new legislation or policies), actual change in people is much slower as cultural norms and values are considered more 'important' than externally imposed rules. This also means that the application of formal rules from a certain successful economy (e.g. western market economies) is unlikely to yield the same results when applied in a different context, particularly where property rights are different, for example, in communal tenure land in South Africa. Thus, institutions are important for economics in that they set the rules of the game for how people transact, share ideas and knowledge. Institutions are important in that they determine the extent and rate at which progress in terms of social and economic development can occur.

2.7.2 Land management institutions and organisational structures

To better understand local institutions involved in the management and use of communal tenure land, a brief history of communal land management institutions is provided in this section.

Butler (2002) identifies four periods in the history of Traditional Leadership in KwaZulu-Natal, namely (1) Pre-Shakan, (2) Political Consolidation (3) Colonial and Union era and (4) Apartheid era. While the history focuses on KwaZulu-Natal, similar processes occurred in the Eastern Cape and resulted in current system of land tenure in both Provinces where this research took place.

Pre-Shakan era (up to late 18th century)

This period saw people living in self-reliant, scattered homesteads (*imizi*), with the household providing labour. Sustenance was obtained from cultivated fields and livestock and resources for both were readily available. Cattle represented wealth, particularly in transfer through the bride-price (*ilobolo*) in marriage. After the household, the clan was the social unit through which people were identified and clan leadership was defined through the male line developed from a common ancestor. Marriages within clans were not allowed and wives from other clans were taken in exchange for cattle. The principal son of a chief inherited most property, could take more wives and produce more children, contributing to a growing dominance of a particular lineage. Chiefdom occurred at a relatively small scale and powers were not particularly significant. The authority of chiefs was exercised in the name of the subjects and consequently, the extent of their authority was determined by extent to which authority was provided to them by their subjects.

During this time, land was considered to be held in trust for the people and a tribe's claim to land would have been established through a recognised right of occupation, established through conquest, occupation or negotiated allocation with another authority. As there was not significant pressure on land, it was not a critical source of conflict. The Chief's ability to allocate good land therefore was important for sustained leadership and control; an inability to provide this would result in followers changing allegiance and choosing to live under the leadership of another chief. Thus a Chief's authority was not primarily derived from coercive power, but from patronage and symbolic power, and power was effectively provided to the chief by the clan members.

Political centralisation (late 18th to mid-19th century)

This period was characterised by political centralisation, conflict and culminating in the ascendancy of Shaka. During this period, existing chiefdoms continued to function largely as they had before, but with increasingly centralised exerted on a core area. The new state formation could be seen as a federation of chiefdoms, rather than a directly centralised union - subjects were still ruled by their chiefs and allocated land, but chiefs were becoming increasingly subject to a central political authority. The underlying economy, however, remained with the productive homestead as the fundamental unit. There was no political space for 'unemployment' or landless people and therefore the political centralisation had to be secured without undermining the sustainability of the homestead. Another important factor contributing to increased centralisation was the introduction of the *amabutho* system, which is thought to have originated from youth cohorts brought together by the chief for circumcision purposes. These young men, who were placed under a Chief's authority for a period of time, could serve the central organisation in a range of ways, from working in the royal lands, bolstering the ability to extract tribute from subjects, to waging war on neighbouring rivals and political threat.

With the birth and rise to power of Shaka during this period of centralisation, by the mid-1820s, Shaka ruled a kingdom of more than 100 000 people and had a standing army of 12 000-15 000 men.

Colonial and Union era (mid-19th to mid-20th century)

In 1824, European settlers established permanent settlement at the bay in Durban. In the mid-19th century, the British arrived and the whole region was annexed as a Crown colony. The introduction of capitalism, which has a different view of land compared with the pre-colonial systems that were in place, changed land access and ownership significantly. Whereas before, land was allocated and shared in a communal spirit, land became commoditised through ownership and exchange as a means of producing profit.

The colonial system enabled white farmers to take what land they could and differentiated this land from reserves in which Africans could access land. This started the progressive marginalisation of Black Africans in Natal. The reserves were insufficient, accounting for approximately one sixth of Natal and could not meet the livelihood needs of the homestead. By the 1890s, the homestead economy was under stress due to increasing and inevitable land shortages. This resulted in increasing migration of labour to work in the colonial farms and towns. This labour pattern, with cash remittances kept the appearance of the homestead economy alive, but as ability to access and allocate new land declined, more young men were forced to take up labour and no longer served the clan *amabutho* system.

As the authority of chiefs was eroded in the latter decades of the 19th century, colonial powers recognised that the power of the Chiefs needed to be bolstered to stabilise the social structures in the reserves. Ultimately, the homestead economy in the reserves collapsed and they became labour reserves, with the social cost of the migrant labour system being externalised to the reserves. The Chiefs still fulfilled an important role in looking after homestead resources while migrant workers were not on the reserves. While the earlier homestead system as an economic and political system had collapsed, there was at least the promise of some security and the allocation of a residential plot. This basic system continued until the introduction of the 1913 Land Act, which set aside 7% of the country for Native Reserves and later by the Native Trust and Land Act of 1936, which ensured that whites control the vast majority of resources and land. The survival of Black Africans living on the reserves became dependent on entering into wage labour.

Apartheid Era (1948-1990)

A brief overview of the apartheid era is particularly difficult, given that it influenced all aspects of life through its destructive nature. This summary focuses on key themes related to the reserves. The National Party recast the reserve system as a system of separate development, the ideology being that the Black African reserves would be the basis for gradual development of tribally and ethnically defined independent countries. Of course, the resources of the reserves were woefully inadequate for this to be achieved, compounded by political and economic marginalisation. Reserves were consolidated into 'Bantustans', and remained heavily dependent on the indirect rule model, where traditional authorities were given greater powers and larger stipends, but still had to operate within the parameters of the apartheid system. As a result of the 'complicity' of the chiefs, and their largely 'autocratic' rule, the legitimacy of the *amakhosi* became questionable. Traditional authorities became ambiguous as far as Black South Africans were concerned; on one hand they were instruments of the apartheid system, while on the other they also mediated and facilitated access to a range of entitlements (e.g. land for homesteads, cropping and grazing) denied to Black South Africans elsewhere.

With the dismantling of the apartheid system, the traditional governance structures remained, although their origins associated with the homestead economy of the 18th century were gone.

This section has provided a background to better understand the current communal land management institutions and systems in place today. Essentially, the original hierarchy associated with traditional institutions remains, however the methods through which authority is dealt with have changed. Another important factor to highlight is that traditional authorities generally ended up ruling their subjects on land with inherently low productivity and dense populations, meaning that achieving economic development and agricultural productivity would be particularly difficult.

2.7.3 Categories of land under communal tenure

To better understand categories of land in communal tenure land, descriptions are provided below of the different types of land use and access, based on the definitions of Cousins (2011). These refer specifically to access to land and natural resources in Muden, KwaZulu-Natal and are divided into three categories (1) the homestead, (2) cropping land and (3) grazing land. Similar processes of land allocation occur in the Eastern Cape (McCosh et al., 2012, p3; Fay, 2006, p7).

The homestead (umuzi)

Residential land for an *umuzi* (homestead) is large enough to establish a homestead garden, bury deceased family members and kraal livestock at night. There are usually some fruit trees and small scale crop production. This land cannot be sold, but buildings can be transacted for cash. Residential land is mostly inherited by a male family member. If a homestead is abandoned and the remaining extended family make it clear that they no longer wish to use it, the land can be re-allocated, but this requires ceremonies to appease the ancestors before transfer takes place.

Cropping fields (amasimu)

Once a family has been allocated arable land, this land is held securely, even if it is not cultivated (this rule is different in other areas and there do exist situations where, theoretically, at least, land that is not cultivated for a certain period of time can be reallocated to other families who require land for cultivation). Fields that are not in use can be borrowed, usually without any exchange of cash, although a gift, for example, a portion of the crop, may be given to the owner of the field or the borrower may plough the owners' field at no cost. Arable land cannot be traded or sold.

Increasingly, there is a shortage of arable land for cultivation, while at the same time some arable land holders are not cultivating their land. A decline in cultivation is attributable to constraints associated with dryland cropping and the general decline in crop production. In Msinga, discussions are being initiated related to the reallocation of fallow land (Cousins, 2011).

Crop residues are considered to be common property for consumption by livestock in the winter months. Owners of livestock that damage crops can be fined. Land holders have first option on other resources that are grown on their arable land, such as thatching grass, after which permission may be obtained for other parties to harvest the thatch.

It was also custom that no-one worked arable lands on a burial day, and sometimes a few days thereafter, however the extent to which this practice is observed is variable and appears to be declining (Cousins, 2011; McCosh et al, 2012).

Common property

Natural resources outside of homesteads and allocated arable lands are considered common property resources – rights to access these resources require membership of the tribe and non-members are excluded from accessing these resources. Access control and management of common property resources varies as does the enforcement of rules in this regard. As far as livestock are concerned, any member can herd livestock on these communal property resources without any restrictions on numbers. Similarly, thatching grass and fuel wood can be harvested however the cutting of green wood is prohibited.

The different land uses that are generally applied in communal tenure areas in the Eastern Cape and KZN are summarised in Table 2.5.

Table 2.5: English, Zulu and Xhosa names for different land use categories

Description	English Name	Zulu name	Xhosa name
Residential land for homestead	The homestead	Umuzi or Imizi (pl)	Umzi
Land within the homestead used for crop production	Homestead field	Izala	Igadhi
Land within the homestead used for vegetable production (usually irrigated by hand)	Homestead vegetable garden	Ingadi	Isitiya
Land either separate from homestead or adjacent to homestead for crop production	Cropping field	Insimu or Amasimu (pl)	Intsimi or amasimini (pl)
Common property used for grazing, firewood collection etc.	Common property	Amadlelo	Amadlelo

2.7.4 Institutional and organisational structures related to the management of communal lands

The description of local traditional governance structures provided below from Salomon (2011) highlights the relationships between the governance structures and their roles in KwaZulu-Natal. Similar systems operate in the Eastern Cape, with slight variations on the naming and function of the role. These relationships are generally not strictly hierarchical, but are geographically defined.

"The iNkosi and the Traditional Administrative Council are the highest decision-making body with jurisdiction over the people (isizwe) and the final arbiter on a wide range of issues. A tribal secretary, paid by the Government, assists the iNkosi and council. The nation comprises different izigodi (wards). The iNdunankulu assists the iNkosi and mediates in disputes between the izinNduna and the people in the wards. The iNduna administers land issues, assisted by a functionary (ipoyisa), as well as the igosa and iqhikiza, who regulate the behaviour of men and women, particularly at cultural ceremonies. The ibandla is a meeting of men who come together to discuss an issue of common concern or to receive information from the iNkosi through the iNdunankulu or iNduna. The smallest spatial unit is the umuzi, a household or homestead. The umuzi holds citizenship, but not as an individual, and is represented by the head of household who attends meetings of the ibandla or igosa. The composition of the Traditional Administrative Council can vary per area, and generally include members of the royal family, respected men, chief iziNduna, and iziNduna. In some areas, municipal councillors (who are democratically elected) also serve as advisers to the iNkosi and the Traditional Administrative Council[2]. The iNdunankulu acts as a prosecutor unless the matter is referred to the Magistrate

[2] The Traditional Governance and Framework Act (2003) stipulates that Traditional Councils should consist of no more than 30 members, depending of the needs of the community concerned, that at least a third of its members

Court. The Magistrate's Court can call on the iNdunankulu to give evidence. Urban migration by men and the impact of HIV and AIDS have resulted in an increase in female-headed and child-headed households. Alcock and Hornby (2004) cite examples from Msinga, where, contrary to custom, a widow was allowed to retain her family's homestead and land." (Salomon, 2011 p30)

Thus, the governance structures within traditional leadership are complex and well defined, built on a set of cultural norms and values that are very well established and unlikely to change significantly in the foreseeable future.

However, the official roles and authorities of traditional leadership remains contested territory. Historically, as discussed in 2.7.2, the chief would have facilitated harmony, playing a key role in conflict resolution, economic viability through managing the allocation of land and land use rights and social and cultural coherence by playing a major role in social and ritual aspects of tribal life. Now, their roles are somewhat different and recently, the social landscape in which traditional authority evolved has changed significantly (Butler, 2002). The changed role of the traditional authorities is compounded by overlapping authorities that impact on people's lives and social processes in communal tenure areas. While democratic local government exists throughout the country, traditional government occurs only in certain areas and a mechanism to integrate these different and often opposing systems of government has yet to be found (Butler, 2002)

Sithole and Mbele (2008) note that a number of authors (e.g. Ntsebeza, 1999, Cousins, 2007 Mamdami, 1996) approach the question of traditional leadership from the perspective that it was a result of apartheid's manipulative measures to legitimise separate development and that traditional leadership should not be sustained in a traditional democracy as it contradicts the core values of freedom and choice, such as the fact that a traditional leadership system that allows for inheritance of leadership is incompatible with democracy and should therefore not be supported by Government. Furthermore, citizens living under Traditional leadership may also be considered not to be true citizens as they are subjects of undemocratic authority that is not accountable to the people. For example, a common characteristic of traditional leadership in South Africa is that women are largely marginalised by a system that favours men via patriarchy and is therefore detrimental to woman's rights in rural areas. There is therefore on-going tension between traditional and democratic governance structures in communal tenure land.

2.8 Factors influencing access to and productivity of land

To better identify requirements for the outscaling of RWH&C, it is necessary to understand the factors impacting on the productivity of communal tenure land. This is discussed below.

must be women, and a further 40% be democratically elected members of the traditional community (Sithole & Mbele, 2008:20).

Productivity can be seen as the efficiency of production and is usually measured in relation to the inputs required (e.g. land, labour, capital) to derive certain outputs or products (OECD, undated). Similarly, agricultural productivity refers to the inputs (seeds, fertiliser, machinery etc.) and other elements, such as labour, expertise and land to produce certain outputs (DAFF, 2011). Many of these inputs, in turn, require access to finance to purchase the inputs in order to produce the necessary outputs. Water use productivity (as detailed earlier) uses water as the basis of productivity and is the amount of net benefits (outputs) in relation to the amount of water used to produce these benefits. (Molden et al., 2007; Molden et al., 2010; OECD, Undated).

It is often reported that subsistence agriculture in communal tenure lands has stagnated, and is characterised by low levels of productivity and abandonment of agricultural lands (Cousins, 2011; Gqokoma, 2005). Benayas et al. (2007) suggests that there are three main drivers responsible for this:

- **Ecological drivers** (or biophysical drivers), such as elevation, soil depth, soil fertility, land degradation, climate and climate change.
- **Socio-economic drivers**, such as markets and market access, rural-urban migration, technology, land tenure systems, farmer age and transport infrastructure (roads and proximity to markets). These factors tend to be more economically driven, through changes in prices, competition with cheaper sources of agricultural products and also be influenced by social factors, for example, age and preference to undertake other non-agricultural economic activities.
- **Unadapted agricultural systems and land mismanagement**, which lead to soil degradation, overexploitation and productivity loss.

Globally, the greatest driver of land abandonment is rural-urban migration from rural dwellers seeking better economic opportunities. Ecological and mismanagement drivers were considered secondary. However, it is often the interaction of the drivers that compound abandonment, for example, where production is limited by biophysical factors (e.g. soil fertility, rainfall), the likelihood if abandonment is greater if socio-economic factors (e.g. access to markets, lack of technology, land tenure) are also impacting on the use of the agricultural land.

2.8.1 Freehold versus communal tenure

Weideman (2004) argues that freehold tenure (or title) is not necessarily superior to usufruct (i.e. communal). Dominant thinking assumes freehold tenure provides farmers with incentives and access to finance to invest in the farms, while, communal tenure presents an obstacle to agricultural development and productivity. However, it is argued that the political and social context has a far greater bearing on farm productivity than tenure arrangements. Furthermore, the terms 'traditional' and 'communal' can be misleading. Traditional management institutions are not static and the systems of land management, use and allocation vary between different traditional institutions.

Weideman (2004) also points out that titling does not necessarily result in increased agricultural production, citing evidence from Malawi, Kenya, Ghana and Rwanda, where investments committed to off-farm investments, such as children's education, are considered to be more worthwhile than increasing productivity. For access to credit, title is one of many requirements and small scale farmers are unable to access credit for many reasons including lack of financial history, lack of a regular income, administrative difficulties and costs and risks to the lender in providing a large number of small loans. Thus, it is rather the unwillingness or inability of financial institutions to provide loans rather than tenure arrangements. Indeed most smallholders secure credit from informal sources, such as family and friends. Regarding the establishment of an efficient land market, Weideman (2004) suggests that indigenous tenure systems are flexible and systems such as sharecropping arrangements allow for landless and commercial small scale growers to access land for production. The development of an efficient land market, on the other hand, is likely to result in dispossession, increased impoverishment and greater social differentiation, as freehold tenure tends to serve the interests of the more wealthy and powerful, who can accumulate more land as a result of their influential positions in local institutions, resulting in greater and on-going income disparity.

2.8.2 Factors influencing productivity and utilisation of communal tenure land

Small scale / subsistence agriculture on communal tenure land is often viewed as wasteful and unproductive, particularly when compared with freehold commercial agriculture. There are many socio-economic and physical constraints to crop production in communal areas and access to markets and support services (extension, information) are important to address this, as are supporting and facilitating more intensive uses of agricultural land. Ability to access arable land is also a major constraint (Maura et al, 2003).

However, some small scale producers on communal tenure land produce food for the market and in other cases make significant contributions to household food security, often under conditions of severe constraints to production. Maura et al. (2003) reviewed 20 selected case studies on cultivation practices in communal tenure land and found that there were few examples where rural residents were able to produce sufficient food to meet their household needs, even though farmers in the same areas were producing crops on a larger scale for markets.

An observation of abandonment in fields in the Eastern Cape found that while fields were being abandoned, there was an increase in the size of homestead gardens and an intensification of production in homestead gardens, which would, to some extent, offset losses in field production. Similar trends were also observed in Limpopo (Maura et al., 2003). This suggests that observations of large areas of abandoned lands may not necessarily be an indication in the declining importance of crop production in communal tenure land. Fay (2013) found a sharp decline in the cultivation of remote fields in Xhora District, Eastern Cape since 1998, with the associated expansion and intensification of homestead gardens. Accompanied with this change has been an increase in the diversity of crops cultivated and an associated increase in the use of inputs.

Hebinck and van Averbeke (2013) found that there was a weakening in the ‘rural equals agrarian’ linkage in two communities in the Eastern Cape, where clear evidence of de-agrarianisation and a reorientation towards income earning was observed. Comparing surveys conducted in 1996 and 2010, it was found during both surveys that 75-90% of the village income was from cash and sources external to the village. Social grants were found to be important sources of income in both periods, with increasing importance in the latter survey. At the same time, the relative contribution of agriculture declined, although many households continued as producers of home consumption. In addition, the near total abandonment of fields is attributed to ‘lack of money for ploughing’, which was understood to be a general lack of money for all the resources necessary to bring a crop to harvest (e.g. inputs, labour, machinery). Linked to the loss of production in fields was a dramatic decline in pig production, which was attributed to lack of grain to sustain the pigs. At the same time, a trend of increasing production in homestead gardens was also observed. The net result is that most food needs are met through cash exchanges and Hebinck and van Averbeke (2013) conclude that this trend probably applies to most of the central Eastern Cape. This new reality suggests that new and creative thinking and policy is required to revive the rural agrarian economy and that leasing and sharecropping are viable options that should be considered.

Gqokoma (2005) points out that in Nongcampa village in the Eastern Cape, 90% of the arable land has not been cultivated for many years and sought to determine whether this was attributable to the communal tenure system. Gqokoma found that the 10% of remaining land that is utilised for agriculture is used largely by public servants and retired individuals who have off-farm sources of income, which indicates that financing is an important constraint to agricultural production. Dengu and Lyne (2007) highlight liquidity problems as a major constraint to investment in crop production, which highlights low wage earnings, low job skills, unemployment and lack of access to credit.

Millar (2010) found in interviews with farmers in Peddie, Eastern Cape, that drought (62%) and irregular rainfall (59%) were reported by non-cultivating respondents as key reasons for their abandonment of land, while a shortage of labour (52%) , poor soil quality (51%), a lack of fencing (23%) and a lack of funding (19%) were also important factors.

A similar questionnaire posed to cultivators of land found that they perceived the main cause of abandonment to be government social grants, while more than half of the cultivators acknowledged that farming had lost its importance in rural communities, with a distinct decline in youth interest in farming perceived by cultivators. Cultivators also highlighted a shortage of labour and laziness of community members resulting in land abandonment, although it was also acknowledged by cultivators that cultivation is costly and many non-cultivators did not have sufficient capital to purchase the necessary inputs for production. Many households experienced declining yields while input costs increased, resulting in returns lower than the cost of cultivation. This, combined with the introduction of social grants has resulted in increasing reliance by households on external financial support to secure their livelihoods and a declining reliance on agricultural production as a livelihood source.

Aliber and Hall (2010) also note a concerning underutilisation of land in communal tenure areas, although they point out that the precise extent is unknown, with various estimates indicating that between 75% and 80% of arable land in communal areas in underutilised. A number of primary reasons for this are cited:

- Shortage of available labour (and an increase in labour costs) as a result of the absence of male labour and constraints on female labour related to domestic responsibilities and urbanisation processes.
- A shortage of draught animals and available manure.
- A shortage of capital and income to purchase inputs due to low incomes and increasing costs of inputs.
- Difficulty in obtaining local sources of agricultural inputs (agrochemicals and land preparation machinery).
- Soil erosion as a result of population pressure and incorrect land use practices.
- Damage to crops by livestock due to labour shortages and lack of fencing.
- Loss of crops to theft as a result of poverty, social inequality and social disruptions.
- Lack of markets for produce from increased competition by the white commercial farming sector and the departure of traders from communal areas.
- Loss of cooperative activities to support agricultural production due to increasing inequalities and declining resource base, such as labour, livestock and finance.

An important traditional practice that appears to be declining in certain areas is the control of livestock during the growing season. This has been noted as problematic as livestock are kept nearer to the homesteads in the summer months due to the risk of theft, the loss of herders and breakdown of institutional sanctions for cattle entering croplands during the growing season (Salomon, 2011; McCosh et al., 2012; Cousins, 2011, Maura et al., 2003). Another factor contributing to this is the decline in cropping itself; with fewer people cultivating, there is little incentive for the entire village to keep stray animals out of the fields, which are generally not well fenced. In turn, farmers concerned about crop losses from livestock are reluctant to cultivate, further limiting crop production (Nondomiso, 2009).

2.8.3 Influence of land administration on land use and productivity

Cousins (2011) notes that securing the rights of people living within communal tenure land systems which are informed by customary norms and values is a key issue in land reform policy. However, land access in communal tenure areas is confounded by conflicting rules of traditional institutions and democratic institutions as enshrined by the constitution. The collapse and mismanagement related to the administration of communal tenure systems is also an important factor influencing use and productivity of land. In many instances, land users have no secure way to lend or lease their land for fear of losing it, meaning that land users keep fallow land for themselves, rather than allowing others to make use of it (Maura et al., 2003, Manona and Baiphethi, 2008).

Dengu and Lyne (2007) experimented with the introduction of rental markets for improved productivity, hypothesising that efficient rental markets create an opportunity cost for under-utilisation, encouraging the transfer of land resources to more effective users. The 'cost' (i.e. disincentives to leasing of land) of the rental transaction in communal tenure land is mainly that rental of land can be considered as evidence that the lessor has no need of the land (40% of respondents in the study believed that they would forfeit their land if it was rented out). With the introduction of formalised agreements with traditional authorities, to mitigate risk of breach of contract and entering into rental agreements with trusted people, such as family and friends to reduce the moral hazard of breach (i.e. the likelihood of breach is reduced when the parties are familiar with each other, compared with entering into an agreement with a stranger or lesser-known person) it was found that efficient rental markets with lower transaction costs (i.e. risks) could be established. However, the development of such markets would require support from external agents such as the Provincial Departments of Agriculture to sanction contracts and ultimately legal reform to formally recognise such contracts to further reduce transaction costs.

Manona and Baiphethi (2008) introduced a simple and cost effective land register to develop rules for local land administration in Thaba Nchu in the Free State. This is in the light of a collapsed land administration system, attributed largely to a lack of a coherent policy and legislative framework since 1994. Essentially there was an institutional vacuum as the withdrawal of the "Permission to Occupy" system was not replaced with an alternative form of legislation, which was compounded by the removal of functions of organisations that were key role-players in land administration. The local land administration authority was provided with powers, including maintaining land registers, facilitating land exchange agreements (lease), investigation, adjudication and resolution of conflicts, and livestock controls (and sanctions, but the compensation value for crop loss was not resolved, although the principle of sanctions was agreed upon). These interventions were well received by the community and allowed for better management of land by land holders. However, strong institutions and organisations are required for on-going good management, which currently are not in place. This threatens the long term sustainability of land administration in the area.

Claasens (2001) found very little agricultural activity occurring in many villages in Rakgwadi, Limpopo Province, including irrigated and dryland arable lands that had not been farmed for years. This contrasted with other villages in the same region, in which impressive levels of agricultural production were occurring, in many cases producing staple crops and in some cases, the production of specialty crops for urban markets, which indicates that good production can be achieved under certain circumstances. A key factor attributed to the success of certain villages in terms of agricultural production was that these groups had managed to maintain and enforce internal rules regarding land use. In terms of areas showing little agricultural production, a number of examples were identified where traditional leadership had not devolved control to a specific user group who could set their own local rules regarding land use and management. Thus as people were denied or lost local rights and control, local agricultural productivity dropped. A number of cases are cited where by unilateral decisions (or in some cases, no decisions being made) by traditional leadership and government has ultimately resulted in lost production and abandonment, which indicate that effective leadership from traditional authorities and the State is necessary to facilitate enhanced agricultural productivity. In addition, Claasens (2001) notes that the best use of agricultural land is more likely to be achieved when control of land use decisions rests with small user groups with vested interest in the lands for agricultural production. These systems of local control are, however, dependent on the support of the traditional authority, who can potentially stop action through making decisions that serve their own ends, delaying decisions or not making decisions at all.

2.8.4 Influence of gender on land access

The patriarchal inheritance and succession system in traditional authority areas can be problematic for access to land by women as these values and rules discriminate against women in terms of not only land use and access rights, but also inheritance rights (often related to land) and participation in local governance and decision making. However, women do have some form of land use rights in the sense that they have a degree of access to land to secure their livelihoods, which does not generally occur outside of traditional authority areas (Butler, 2002). Denison et al. (2015), however, found no evidence of rules that were discriminatory towards women in three villages in the Eastern Cape. These differences suggest that in the absence of a common legislative approach to land tenure, divergent practices in relation to land allocation occur, especially with regard to access to land by women in communal areas.

2.8.5 Discussion

Considering the driver descriptions of land use change noted by Benayas et al. (2007), it appears that the predominant drivers of productivity and land use in communal tenure areas are ecological (related largely to rainfall) and socio-economic (primarily related to land administration and access to finance / cash). It is not a given that freehold tenure will be more productive and indeed, other socio-economic factors play a more important role. Land abandonment due to lack of finance or cash and drought are important drivers, however land administration and the functioning of institutions responsible for land administration appear to be a major impediment to the productive use of land. The perceived insecurity of tenure where land is rented, resulting in landholders preferring to keep their land fallow rather than renting it out for fear of losing it is another challenge.

Aliber and Hall (2010) point out that the most significant asset for developing small scale farmers are small scale farmers themselves, meaning that interventions should not stifle individuals' initiative and talent, nor should farmers be treated as passive recipients of knowledge and support. An enabling environment should be created to allow them to reach their potential. Also, efforts to support farmers should focus on those already actively farming. Finally, and importantly, interventions should not be imposed in a top-down manner, but rather in a cooperative, participatory manner.

2.9 Factors influencing management of livestock and communal rangelands

This section draws largely on the work of Salomon (2011) who conducted extensive research on the management of livestock on communal tenure land.

2.9.1 The value of livestock in communal areas

Pastoralism, or the keeping of livestock, is an important livelihood strategy employed by people living in arid and semi-arid regions throughout the world. Livestock play an important and diverse role in rural society and rural livelihoods and livestock keeping systems are dynamic and fluid, shifting and changing in response to economic, social and environmental changes (Salomon, 2011).

In southern Africa, livestock connect people and enhance social cohesion, fulfilling practical, cultural and spiritual functions. From a practical perspective, cattle and donkeys are used as draft animals for ploughing of lands and transport of goods to rural, often inaccessible areas. From a cultural and spiritual perspective, the ritual slaughter of goats and cattle to honour ancestors and perform various ceremonial functions is an important part of the urban and rural cultural landscape. The traditional custom of '*lobola*' or bride price, whereby cattle are exchanged for wives is an example of social exchange to strengthen communal and familial bonds. Livestock are also important economic assets that provide goods such as meat, milk and hides as well as providing financial services such as insurance and risk mitigation from a food security and financial perspective (Salomon, 2011).

2.9.2 Traditional rules and governance of communal rangelands

Historically, it was common practice in communal areas that summer grazing of livestock occurred in areas further from the homestead. This practice ensured that livestock are kept from entering and damaging summer crop production fields and makes use of good quality fodder in rangelands further away from the homesteads. In winter, livestock would graze closer to the homesteads and make use of available fodder and crop residues to help to maintain them during winter.

Traditionally, the induna (local headman) would announce when cattle should move to the summer grazing areas and when livestock could be moved closer to the homesteads for winter grazing. Salomon (2011) notes that the not all livestock owners follow the induna's instructions and that there is an erosion of traditional authority regarding the management and movement of livestock. While many people did recognise the authority of traditional leaders in general sense, traditional leaders were not able to exercise their authority in the management of communal rangelands.

Salomon (2011) notes that challenges regarding communal rangeland are complex, but that the key factors influencing grazing management are the issue of stock theft and the lack of authority of traditional leaders in controlling the movement and management of livestock. Herding of livestock is traditionally considered to be a family matter, where family members are responsible for this. The introduction of compulsory schooling, remittances and the recent introduction of social grants have in many cases resulted in a 'hands free' cattle grazing management approach whereby limited herding of livestock occurs As a result, livestock are generally kept close to the homestead all year round, increasing pressure on nearby grazing. Stock theft is also perceived to be a significant threat to livestock and, given the lack of herders, is another reason for keeping livestock close to the homestead. Investigations by Salomon (2011) found that stock loss due to disease was equally problematic and that interventions to control livestock disease were also necessary.

Salomon (2011) found that although stock theft and livestock disease were equally pressing matters, she noted that stock theft increases the lack of trust and social cohesion and posited that with the establishment of a cattle patrol to control stock theft, a reverse in the decline of cattle can be achieved and trust and social cohesion can be restored. In so doing, local leadership can emerge and local rules can as a result be established to improve the management of natural resources.

2.9.3 Governance and regulation of rangeland management practices in communal rangelands

Historically, access to and use of open access communal tenure resources such as rangelands was managed through traditional institutions and enforced by traditional authorities. Traditional rangeland management practices regulated the use of range resources and users defined specific areas for use, monitored users of resources, applied sanctions, resolved conflict and adapted rules where necessary (Salomon, 2011).

While pastoralists and croppers have co-existed for centuries, economic and socio-political changes have resulted in increased competition over resources, resulting in tension and conflict. This is particularly relevant where production systems overlap, such as in livestock and cropping systems. In particular, where geographic or political boundaries are limiting and mobility is restricted to demarcated grazing areas, loss of traditional rangelands and competition between pastoralists and croppers for resources occurs. This can result in problems of degradation and over use (Salomon, 2011).

2.9.4 Productivity of grazing on communal tenure land

Conventional rangeland science applies the concept of carrying capacity to establish the concentration of livestock necessary to maintain a healthy and productive herd while ensuring sufficient plant regeneration. Conventional grazing systems usually involve a rotational system where pastures are rested on a regular basis to allow the regeneration of plant material (Salomon, 2011; Briske et al, 2008). Conventional rotational grazing systems are associated largely with commercial livestock production systems on privately owned farm land.

Continuous grazing, as the term indicates, refers to on-going grazing of the land without periods of rest to allow plant material to recover. This type of grazing system is usually associated with communal managed rangelands.

Salomon (2011) notes that the 'Tragedy of the commons' narrative dominates current thinking and in turn dominates policies that regulate the management of communal rangelands. Interventions in communal rangelands, as a result, focus on commercialisation of livestock management systems by imposing rotational grazing systems and controlling animal numbers to maintain rangeland equilibrium. These interventions have had little success as they do not take cognisance of the fact that livestock keeping is a 'multi-dimensional phenomenon in which access and benefits from livestock products are regulated through social and cultural norms and that rotational grazing is not superior to continuous grazing' (Salomon 2011: 24). Current thinking and policies regarding the management of communal livestock also do not fully acknowledge that pastoralists have well established and sophisticated methods of dealing with fluctuating climatic, agro-ecological, economic and political conditions.

Maura et al. (2003) argue that the productivity arid and semi-arid rangelands are systems driven largely by rainfall, fire and other episodic events. They are highly resilient and recover rapidly after droughts or periods of rest. Thus the conventional indices of overgrazing are subjective and based largely on commercial indicators of how a rangeland should look in a particular area.

Salomon (2011) further notes that policies are resulting in problems of degradation and over-use as they favour cropping and the limiting of livestock movement and argues that a more holistic and systemic view of livestock keeping is required to enable scientists and development practitioners to better understand the complexity of the system and support better livestock management in communal rangelands.

Briske et al. (2008) found that continuous grazing systems were as productive and in some cases more productive than rotational grazing systems, in terms of animal production and plant production. De Bruyn (undated) had similar findings in a trial in the central Eastern Cape Province, finding that lower standing biomass in communal tenure land, when compared with 'well managed' control site with rotational grazing and controlled stocking rates, did not equate to lower productivity. Thus, it is erroneous to highlight one particular management system as superior to the other, as they are subject to the same environmental constraints, such as climate, soils, vegetation type and condition, and previous land uses. The extent to which a grazing system is effective depends, rather, on how well it is managed, which is in turn dependent on social and institutional considerations, such as commitment to management, the goals of the management system and the ability of actors to effectively manage the system.

Salomon (2011) challenged the prevailing view that overstocking and overgrazing result in soil erosion in areas under communal land tenure, demonstrating that the degree of erosion in the study area showed small fluctuations over the last 65 years. It was also noted that livestock numbers had decreased by 21% between 2001 and 2010, which may have reduced the overgrazing effect of the more recent practice of grazing livestock continuously and closer to the homesteads.

Salomon (2011) highlights that pastoralists have developed well-adapted practices to deal with the variations in climatic conditions through mobility of herds (moving livestock to areas of better grazing), varying herd size and diversifying animal breeds. Given that rotational grazing systems are not necessarily better than continuous grazing systems and that pastoralists can apply adaptive grazing management in communal rangelands, the importance of institutions and organisations in herd management strategies becomes relevant.

Salomon (2011) notes that “degradation and overpopulation narratives” are often associated with projects aimed at improving community based natural resource management. Multiple drivers influence livestock keeping practices, with social, economic, political and ecological factors applying pressure internally and externally and at different scales. Consequently, interventions in complex situations such as rangelands are fluid and need to respond to the dynamics of the various drivers influencing livestock management and rangeland access. Salomon (2011) describes cattle keeping in Okhombe “as being embedded in a social-ecological system comprising a series of nested, self-organizing sub-systems which are interconnected”. This aptly describes the complexity and systemic nature of livestock keeping in communal rangelands. To effectively respond to changes in the socio-ecological landscape, the importance of putting livestock keepers first is necessary for the development of appropriate needs-based policies, but all interventions should be viewed in the context of a dynamic and fluid system and therefore should evolve over time.

2.9.5 Discussion

Key findings by Salomon (2011) were that policies and interventions need to recognise that:

- Pastoralism is a multi-dimensional phenomenon in which access to and benefits from livestock products are largely regulated through social and cultural norms.
- Pastoralist practices can ably manage the fluctuating climatic, agro-ecological, economic, and political conditions.
- Generic grazing schemes do not work because cattle keepers have different objectives that inform their practices to manage their livestock.

- Land degradation is the historical outcome of interactions between ecological, socio-political, and economic processes and interactions at different scales, and not singularly caused by incorrect grazing management practices.
- Tension and conflict between local government and national government, and between traditional leaders and civic leaders constrain collective action and effective management of the rangeland commons.

Further recommendations include that single discipline approaches have failed to generate solutions that deal with the complexities of livestock keeping and rangeland management and that a systems approach is necessary to allow stakeholders 'to intervene in a dynamic context dictated by interacting biophysical, socio-political, and economic variables'. The shift in range and forage policy from monitoring and control to promoting a culture of sustainable management is supported, but the voices of livestock keepers need to be more central to the debate and incorporated into policy.

Thus, as with cropland productivity, key factors influencing rangeland productivity are ecological and socio-economic. Again, a key factor influencing the management and productivity of livestock in communal tenure areas is the lack of governance and the enforcement of rules in communal rangelands. Another important factor is the risk of stock theft, which is perceived to be a greater threat than loss due to disease.

Evidence also indicates that the overgrazing and the 'tragedy of the commons' narrative does not necessarily hold true. Rangelands in arid and semi-arid areas are resilient and can recover quickly from periods of drought. Furthermore, continuous grazing systems are not necessarily less productive than rotational grazing systems. However, with the trend of keeping livestock closer to homesteads due to a lack of herders, it can be expected that continued intense grazing pressure in these areas will result in degradation.

2.10 Summary of the literature review

Rainfed agriculture dominates world food production and thus RWH&C has the potential to provide significant social, economic and environmental benefits. This is particularly relevant in sub-Saharan Africa where 93% of farmed land is rainfed (Rockstrom et al., 2007; Botha et al., 2007).

RWH&C is the process of concentrating rainfall as runoff from a larger catchment area to be used in a smaller target area. Collected runoff is either applied directly to an adjacent field or is stored in some type of reservoir (Oweis et al., 1999).

Micro-catchment RWH&C is the subset of RWH&C techniques and includes the systems and practices which concentrate rainwater from a larger to a smaller area within a specific field and stores this runoff in the soil profile. Water conservation systems that enhance the productive use of harvested rainwater are considered important complementary practices that should be applied when in-field RWH&C systems are established (Oweis et al., 1999; Rockstrom et al., 2007).

A major limitation in the application of RWH&C in South Africa appears to be that of slope and soil depth, which is important, considering that past discriminatory settlement patterns, have resulted in settlements often being in hilly areas with marginal soils. Systems that concentrate rainwater, even on marginal and shallow soils, do have potential to increase and stabilise crop yields, particularly when used in conjunction with other soil conservation practices, but must be managed carefully so as not to exacerbate soil erosion (AFDB, 2008; Critchley and Siegert, 1991).

When implementing RWH&C techniques, it is important to match the design with the biophysical conditions at the site, considering in particular soil, rainfall and runoff. Considerably more important, however, is due consideration of the communities themselves. RWH&C interventions must put people at the centre of development and ensure that other higher livelihood priorities have been addressed, or that RWH&C will contribute significantly towards addressing these priorities (Critchley and Siegert, 1991; Botha et al., 2007). From a social and cultural perspective, it is necessary to consider prevailing socio-cultural norms and values and ensure that firstly, RWH&C is compatible with these values and secondly that higher level socio-economic priorities have been addressed or will to some extent be addressed by RWH&C, in order to ensure uptake of the practice (Rockstrom et al., 2007; van Averbeke, 2004).

Water use productivity in crop and livestock production systems is an important consideration in this research project. The contribution of RWH&C interventions to increased water use productivity will be measured through changes in biomass production and harvestable yield. In terms of evaluating LWP, the conceptual framework of Descheemaeker et al. (2010) will be applied in the field research associated with this project (Figure 2.10), with a specific focus on feed quality and quantity. A key focus of RWH&C in the croplands is to increase the beneficial consumption (transpiration) of water to achieve higher levels of water productivity.

Institutions represent mental models of how the world works and dictate actions and decisions and are largely culturally derived through the intergenerational transfer of norms and values that govern how society behaves. Norms and values that govern behaviour are slow to change and changes in formal rules (e.g. legislation) are unlikely to result in rapid changes in 'informal' rules (i.e. norms and values). These norms and values dictate the rate and extent to which social and economic development can occur (North, 1992).

Communal tenure land in South Africa, as it stands today, has emerged from a long history, starting prior to the 18th century, as a relatively harmonious system building on dynamic social processes with the homestead as the basic economic unit. With the arrival of colonialism and, subsequently, apartheid, Black South Africans were dispossessed of large areas of land and forced to reside is areas where land was limited, resulting in land shortages and the collapse of the homestead as the basic economic unit, forcing people to migrate to urban areas and to commercial farms to earn cash. The homestead is still the basic unit and the traditional rules regarding allocation of land for homesteads and field crop production reflect this. Areas outside homesteads and arable fields are common property resources and are used for the grazing of livestock and harvesting of natural resources by all community members. The role of traditional authorities remains important in communal tenure land and the traditional structures are well established. It is argued that these institutions are incompatible with democracy and the Constitution as they contradict values of freedom and choice, favour patriarchy and are largely not accountable to the people they govern. Furthermore, due a lack of a common set of rules for land management in communal areas, there are divergent land administration practices. These variations create greater uncertainty in terms of land tenure in communal areas (Butler, 2002; Cousins, 2011).

Communal property resources consist of three elements: the homestead, the homestead garden, cropping fields, and common property. The homestead and homestead garden are usually located in the same space and individual user rights prevail. Use rights are generally transferred intergenerationally through the male lineage. However, women are increasingly obtaining use rights for homesteads. Cropping fields have individual user rights during the growing season but they become common property in winter as a shared grazing resource for the communal herd. Common property consists of natural resources outside of the homestead and fields, which consists mainly of grazing land. Rights of access require membership of the community and non-members are excluded from accessing these resources (Cousins, 2011; McCosh et al., 2012).

There is a general consensus that productivity of croplands in communal tenure areas has declined largely due to socio-economic and biophysical constraints (notably, rainfall or lack thereof). From a socio-economic perspective, abandonment of land can be attributed to rising input costs and lack of access to finance, lack of labour (particularly family labour) and land administration and management. Hebinck and van Averbeke (2013) found that there was clear evidence of de-agrarianisation in the Eastern Cape and a reorientation towards income earning. Other studies found similar trends, which attributed to the lack of resources to bring a crop to harvest from the fields and a trend towards homestead garden food production (Gqokoma, 2005; Lyne, 2010). There is also some evidence that government social grants, by reducing reliance on agricultural production, are contributing to the abandonment of land (Millar, 2010). Importantly, common property institutional arrangements have a strong bearing on how people organise themselves to produce food. Where there is erosion of institutions (traditional and constitutional), there tends to be a decline in productivity. Examples from the literature show declining control of livestock resulting in crop losses is also a common driver of abandonment of field production (Salomon, 2011; McCosh et al., 2012; Cousins, 2011, Maura et al., 2003).

Continuous grazing systems as applied in communal tenure areas can be as productive as rotational grazing systems. Either system is subject to the same environmental constraints, most notably, rainfall. Arid and semi-arid rangelands are resilient system and recover rapidly after periods of drought. The degree to which a grazing system is effective rests largely on how it is managed, and this depends on social and institutional considerations, such as commitment to management, the goals of the management system and the ability of actors to effectively manage the system (Salomon, 2011; Briske et al., 2008)

Where strong leadership with vision is applied by traditional authorities, it appears that agricultural productivity can be maintained and enhanced. This is particularly important where control of land-use decisions can be vested with small user groups with a vested interest in production. It is therefore important to support smallholder farmers who are currently farming and seek to support the emergence of institutions that can support such farmers (Manona and Baiphethi, 2008; Claasens, 2001).

Livestock still play an important cultural, spiritual and economic role in rural areas. The erosion of authority related to the enforcement of traditional rules is problematic and traditional authorities are often not able exert their authority when it comes to the administration of common property rangelands. Due to a loss of labour and fear of stock theft, livestock are often grazed close to the homestead where they can be watched. This is resulting in fodder shortages in winter, as traditionally livestock would graze close to the homestead in the winter months this change in livestock movement is also placing significant grazing pressure on rangelands close to the homestead and could accelerate degradation in these areas (Salomon, 2011).

Based on this review, it is clearly important that the effectiveness and functioning of local institutions regarding the management and utilisation of crop and rangelands is an important factor influencing water productivity.

3 RESEARCH METHOD

This chapter provides an overview of the site selection process and describes the methodological approaches to the research.

3.1 Research site selection

The process for site selection considered a set of criteria that were based on the project objectives. Key criteria used are provided in Table 3.1.

Table 3.1: Criteria for the selection of research sites

Criterion	Parameter
Tenure arrangements	Communal tenure
Existing working relationships	Preferable if one site could build on existing work (upscaling) and another new site could be established (outscaling)
Existing support	There should be existing government support or support from other projects / programmes for sustainability beyond the project
	There should be active extension support in the area
	Ideally the area should be a priority area for development (e.g. CRDP, Massification, etc.)
Agricultural systems	There should be a combination of livestock and cropping
	There should be some dryland cropping activities
	Fencing in croplands to exclude livestock is preferable
	Fencing or systems to control livestock movement (e.g. herders) should be in place
	Existing agricultural activity in both fields and homestead gardens
Biophysical	Rainfall 550 – 750 mm pa
	High evaporative demand
Soils	Soil depth > 500 mm
	Loamy to clay soils that have some water holding capacity (WHC)
Socio-institutional arrangements	Ideally a combination of individual and communal production plots
	Supportive community structures
Logistics	Within a reasonable travel distance (500 km), making Eastern Cape and KwaZulu-Natal the preferred provinces
	Year round access by road
	Reasonable proximity to inputs and markets (costs and income potential)

Three sites located in the Eastern Cape and two sites in KwaZulu-Natal were evaluated based on the above criteria and two sites were selected, namely Muden in KwaZulu-Natal and Ntshiqo in the Eastern Cape. The two sites were well suited in terms of the criteria considered, but also offered contrasts in terms of climate (Ntshiqo has higher rainfall and is cooler, while Muden has lower rainfall and is warmer), livestock (Ntshiqo is cattle and sheep dominated while Muden is cattle and goat dominated) and settlement pattern (Ntshiqo is a consolidated rural settlement as a result of betterment planning while Muden consists of dispersed rural settlements) which would add diversity to the research mix.

Detailed descriptions of the sites are provided below.

3.2 Detailed site descriptions

3.2.1 Ntshiqo, Eastern Cape (Site 1)

The Ntshiqo site is located within the Mhlontlo Local Municipality (LM), OR Tambo District, in the Eastern Cape. Ntshiqo, being near to the town of Tsolo, is accessible via the N2 national road between Kokstad and Umthatha, approximately 50 km from Umthatha. The research sites were all located within the Ntshiqo village, which is part of Ward 7 of Mhlontlo Local Municipality (Figure 3.1).

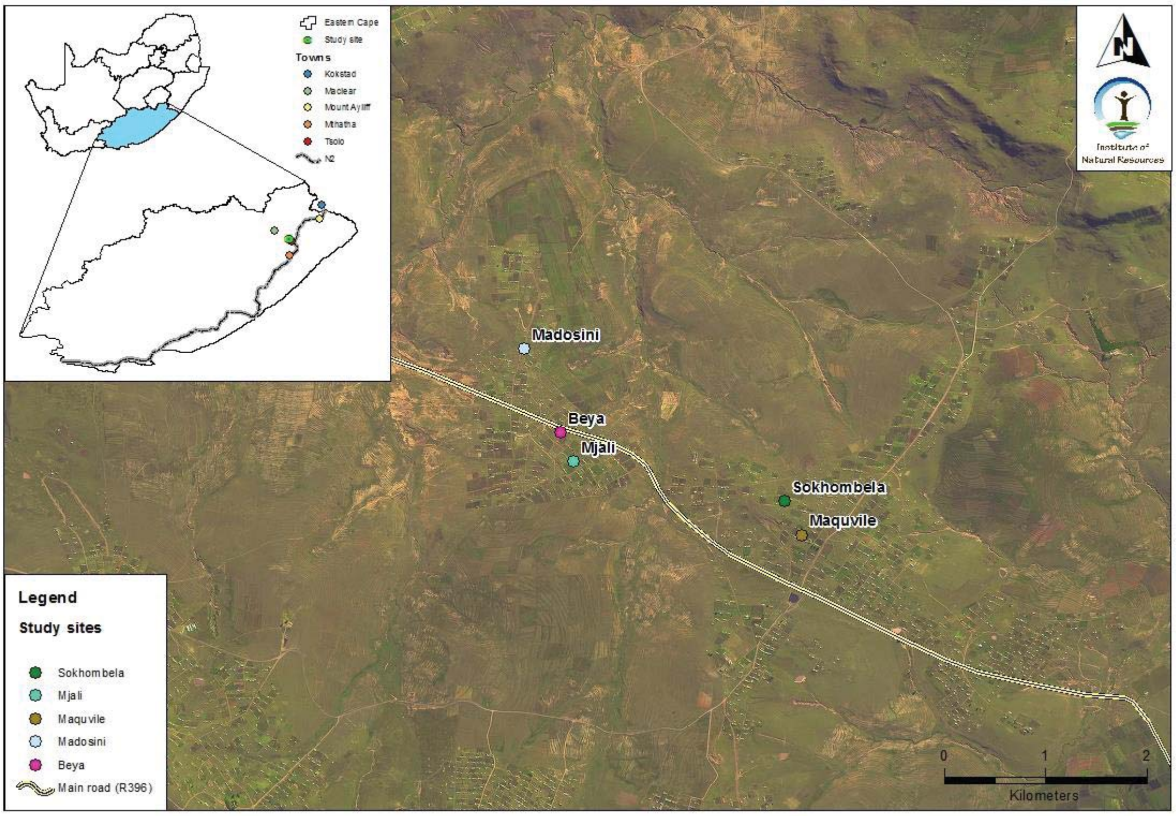


Figure 3.1: Locality map indicating the location of the five Ntshiqo research site, Eastern Cape

Socio-economic overview

The Mhlontlo LM, which is predominantly rural, hosts Tsolo and Qumbu as local service centres, and is located along the N2 that runs through the municipality from the southwest to the northeast. The primary land use outside of the towns is communal use for agricultural purposes and subsistence farming, mainly grazing. The Mhlontlo LM is 2 826 km^2 in extent.

According to the Mhlontlo Integrated Development Plan (IDP) (Mhlontlo LM, Undated), the municipality has one of the fastest growing populations in the District, with a population growth of about 2.84%. The average household size is 4.8 persons per household living in predominantly rural dwellings at an average density of 84 persons per km². According to the Census 2011 (Statssa, 2012), the municipality has a population of 188 226 (100 786 women and 87 440 men) living in 43 414 households. Ntshiqo, in turn, has a population of 827 (462 women and 365 men) people living in 160 households.

The Mhlontlo IDP notes that the area has a comparative advantage in agriculture and forestry, but notes that the contribution of this economic sector to the gross domestic product (GDP) of the Municipality has decreased by more than half (from 8.3% to 3.3%) between 1995 and 2008. This decline is attributed to a lack of investment in economic infrastructure, including roads, electricity and fencing of small farms. The lack of infrastructure is compounded by an absence of business support services targeted at supporting subsistence farmers.

Biophysical characteristics of the study site

At a municipal scale, 25% of the land area is used for some form of cultivation. This may be an over-estimation as many arable lands are no longer being cultivated. Grasslands (including grasslands, thicket and bush) make up 50% of the land cover.

Table 3.2: Land cover in Mhlontlo municipality

Land cover classification	Area (ha)	Percentage
Barren rock	205	0.1%
Cultivated - temporary - semi commercial / subsistence dryland	44 798	25.8%
Degraded: unimproved grasslands	82 218	47.3%
Dongas and sheet erosion	328	0.2%
Forest	3 808	2.2%
Timber plantations	21 509	12.4%
Improved grasslands	9	0.0%
Thicket and bush	8 355	4.8%
Urban / built up (residential)	12 387	7.1%
Urban / built up (smallholdings)	7	0.0%
Water Bodies	157	0.1%
TOTAL	**173 781**	**100.0%**

The Ntshiqo study area is 16 861 hectares in extent (Figure 3.2), made up of semi-commercial/subsistence dryland-3 443 ha (not all this land is currently used for crop production and much of this is grazing land); degraded: unimproved grassland-11 060 ha and urban / built-up land: residential 2 358 ha (this includes homestead gardens used for crop production).

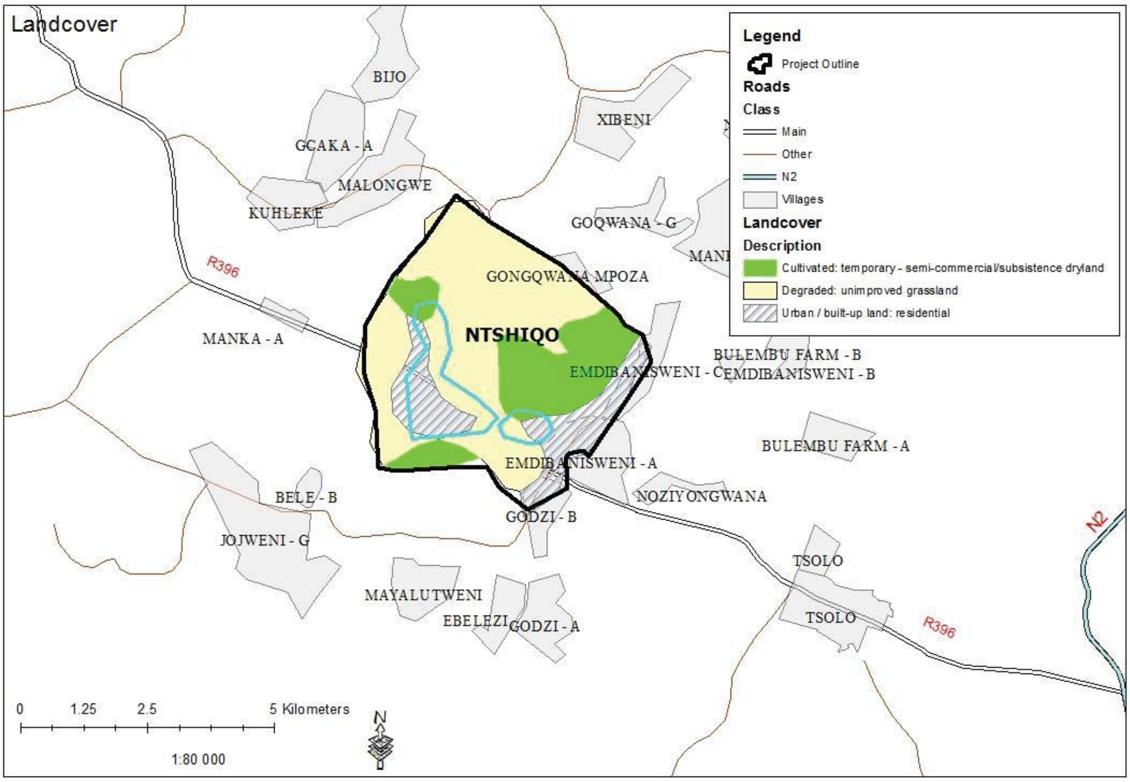


Figure 3.2: Land cover in the Ntshiqo study area, Eastern Cape

Mean annual precipitation in the study area ranges from 580-661 mm per annum, with a mean annual temperature of 16°C. Table 3.3 provides an overview of monthly precipitation, temperature and frost occurrence.

Table 3.3: Rainfall and temperature data for Ntshiqo, Eastern Cape (Source: https://en.climate-data.org)

Month	Median monthly precipitation (mm)	Mean monthly Temperature (°C)
Jan	94	20.29
Feb	88	20.5
Mar	83	19.29
Apr	34	17.1
May	12	14.1
Jun	5	11.3
Jul	6	11.5
Aug	11	13.1
Sep	30	15.3
Oct	54	16.4
Nov	74	18
Dec	85	19.4
Annual	**641 mm**	**16.4**
Frost Frequency (% of years with heavy frost)		94.09
Frost: Number of occurrences per year		4

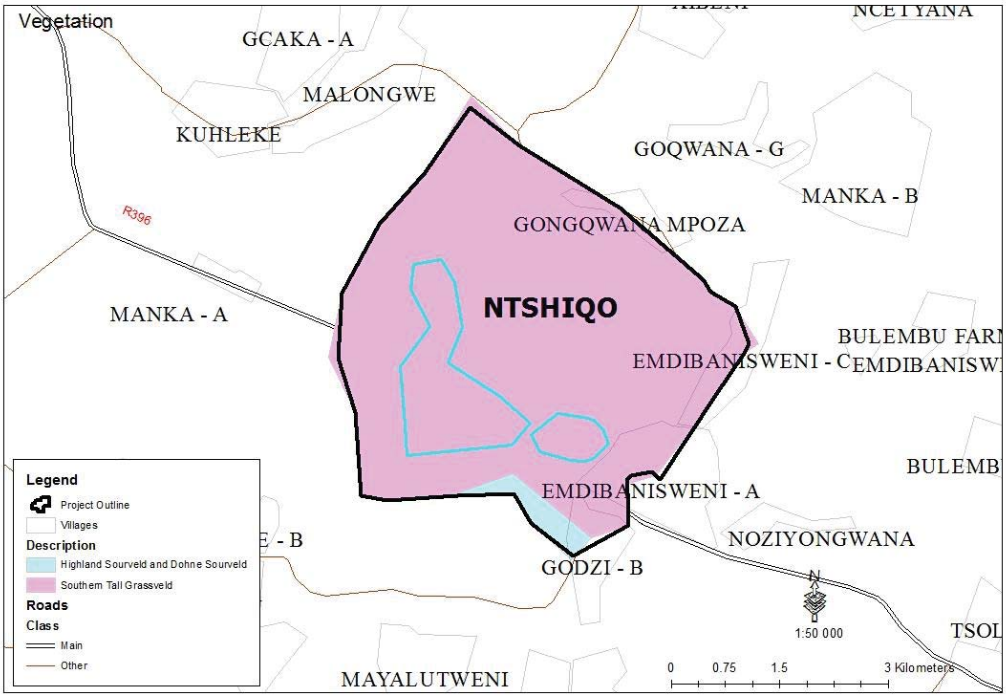


Figure 3.3: Vegetation types within the study area

The dominant vegetation type is Southern Tall Grassveld, with a small proportion of Highland Sourveld and Dohne Sourveld (Acocks, 1998).

Research participants

Through engagement with the traditional authority and through public meetings, five farmers actively farming their homestead gardens were ultimately identified for the research team to work with at Ntshiqo. Initial engagements also included farmers who were farming fields of 1 ha in extent. However after further investigation, it was discovered that these farmers were participating in the government-funded massive food production project (MFPP), which involved no-till farming and the use of glyphosate. Farmers that were initially engaged showed no interest in testing RWH&C in their fields and as a result, it was decided to focus on homestead gardens. The five farmers who participated in the research were Mr Kenneth Beya, Ms Portia Mjali, Ms Madosini Nkompela, Ms Gloria Quvile and Mr Baweni Sokhombela.

3.2.2 Muden, KwaZulu-Natal (Site 2)

Socio-economic overview

The Muden research sites are located in Msinga Local Municipality which is largely rural, with 69% of the Municipal area under communal tenure and under the jurisdiction of traditional authorities (TA), where land is held in trust by the Ingonyama Trust. It is estimated that 99% of the population in Msinga lives in traditional areas.

Muden is accessible via the R33 road, linking it with Dundee, Ladysmith, Pietermaritzburg, Kranskop and Weenen. The Muden area occurs on both sides of the Mooi River (). The southern side of the Mooi River is private freehold land, with commercial irrigation occurring near to the Mooi River. The northern side of the Mooi River is communal tenure land and is where the research is taking place. The Mooi River Irrigation Scheme (MRIS) is a flood irrigation system on communal tenure land, as shown in . Moving northwards and westwards from the Mooi River, the land rises steeply and is classed as Valley Bushveld. This land is characterised by rocky ground and shallow soils with many Acacia trees, Euphorbias and other plant species adapted to the hot and dry conditions that typically occur in the Thukela and Mooi river valleys within Msinga. Apart from the deep alluvial soils located in the flood plain of the Mooi River, there is limited arable to the northwest, due to a combination of shallow and rocky soils, steep slopes and low rainfall. The area is classed as semi-arid with rainfall ranging from 550-750 mm pa with a high evaporative demand, where temperatures regularly exceed 30°C in summer. There is significant land degradation in the area and a general decline in dryland agricultural production. Livestock, in particular goats, are a key part of the agricultural system due to the bushveld nature of the region.

Two sites were identified in Muden for this research project, which both fall under the Mchunu Traditional Authority. These sites are shown in and described in more detail below.

Thengele (Fabeni): This site is located on a plateau above the Mooi River valley. The land is flat, with shallow lithic soils (depth of 400-600 mm). The areas is fenced and has been used for dryland agriculture for over forty years, with the main crops being maize, sorghum, pumpkins and uchokwane (Teppary bean – a small white bean adapted to local conditions and cultivated by dryland farmers). From a social perspective, the group is managed by a group of men who farm individually allocated plots of land within the fenced area. The members of Fabeni are all of the local clan ‘Zulu’. Mr Xoshimpi Zulu and Mr Mntungane Zulu participated in the demonstrations at this research site.

Mxheleni: This site is located on moderately sloping terrain with shallow to moderate lithic soils (depth of 400-800 mm). A variety of vegetable crops are planted on this land along with maize. This site has been allocated to group of women (Mxheleni women’s group) who farm part of the land collectively and part of the land individually. Management decisions are taken by a management committee, let by Ms Mavis Ngqulunga.

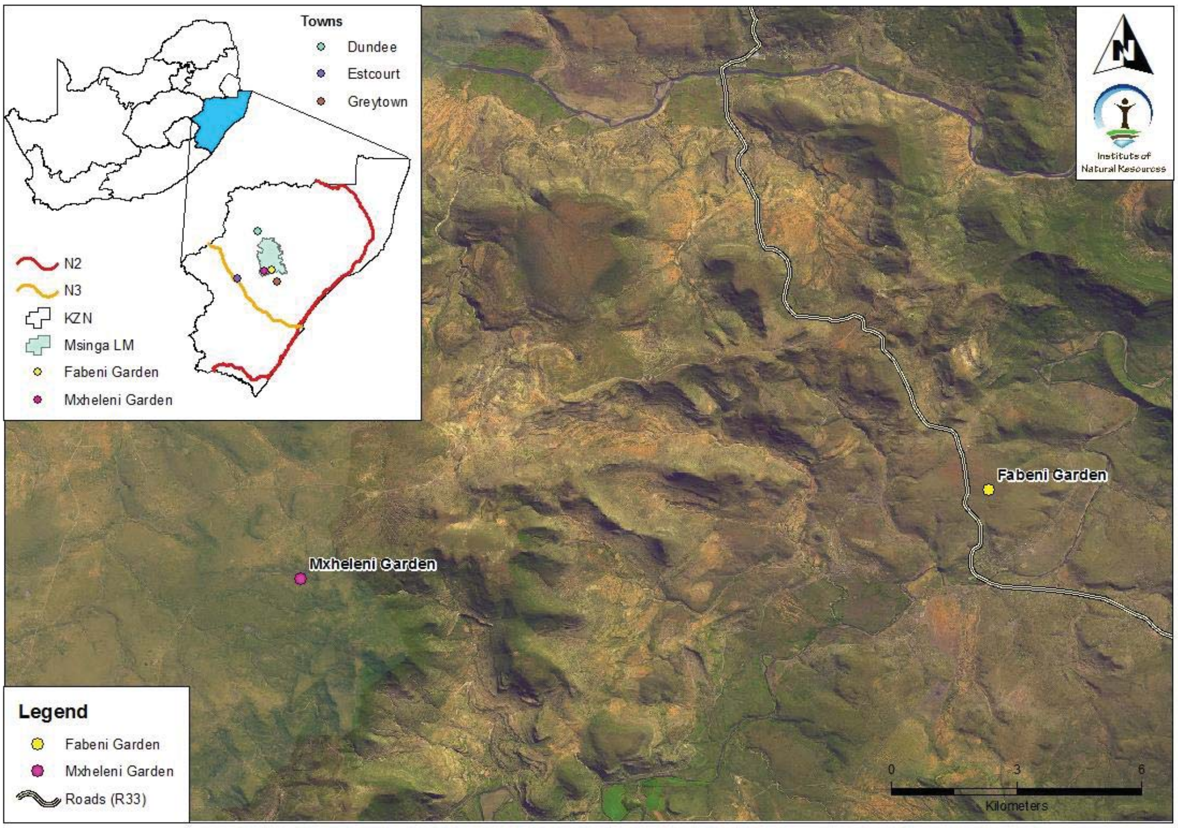


Figure 3.4: Locality map indicating the location of the two Muden research sites, KwaZulu-Natal.

The two sites in Muden are therefore quite different in terms of the biophysical characteristics, with Fabeni being a mid-slope plateau area, while Mxheleni is at the highest altitude, on a relatively steep, north-facing slope. The sites also have different social, institutional and organisational arrangements. This provides the opportunity to better understand the influence of different arrangements on how land is used and whether this will influence the adoption of rainwater harvesting techniques.

Biophysical characteristics of the study sites

Rainfall in the study area ranges from 400 to 900 mm per annum, although the study sites are located in the band of rainfall that ranges from 618-783 mm pa.

Soils in the area are dominated by Eutric and Dystric Regosols, comprising mainly shallow and poorly formed soils. Lithic soils such as the Glenrosa and Mispah forms are typical in the uplands areas while deeper soils, often with poor drainage, occur in the valley bottoms and lowlands. These soils are typical of arid and hot areas, as occur in Muden. The sites fall into the Valley Bushveld Bioresource Group (based on Camp, 1995).

3.3 Research approach

The research approach and methodology were developed, building on the literature review and considering the project aims and objectives. The research approach consisted of participatory action research and empirical field based research on rainwater harvesting.

3.3.1 Participatory action research approach

The overall approach adopted for the research was that of Participatory Action Research (PAR). Quixley (2008) points out that PAR is a fundamentally different kind of research that focusses on processes that encourage the participation of stakeholders throughout the research process. PAR involves an on-going cycle of action and learning and involves planning, action, observation and reflection. It is therefore not linear, but is rather an on-going and fluid process. Consequently, PAR is a highly participatory form of research, where all stakeholders, especially the farmers, are treated as experts, with capacity to engage in the research process. The values which underlie PAR include:

- A culture of inquiry, learning and change is essential to achieving best practice.
- Every stakeholder is of value and has ideas to contribute to service development.
- Service participants have special expertise related to service focus, priorities and design.
- The extent of influence of different stakeholders should be commensurate with the effects of the outcomes on them.
- Those affected by the outcomes of research should be involved throughout the whole process.
- All research is influenced by values - to be effective, research must acknowledge, legitimise and promote the importance of values in its development.
- Having a clear values base to service provision is critical to quality of service.
- For research to be effective, it must be integrated with development.
- The problems / questions for research must be generated from a recognised stakeholder need.
- A collaborative approach amongst all involved is essential to achieving optimum outcomes in the long term.

Farmers participated in the planning process, both in terms of the selection of RWH&C techniques and design of the treatments. Farmers were engaged through workshops and focus group discussions (FGDs) to understand the specific challenges they are faced with in terms of crop and livestock production in dryland systems. Interviews were conducted to identify broader issues (e.g. tenure issues, institutional challenges) which need to be considered. A semi-structured approach was used in workshops and FGDs to allow people to tell stories that provide a rich picture of social and cultural factors influencing land access and land use and also allow the interviewer to interrogate answers that were obtained. The purpose of this approach was also to identify potential case studies to illustrate certain points where possible.

Figure 3.5: Meeting with Ntshiqo stakeholders – 13 June 2013

The identified RWH&C interventions were implemented over three growing seasons at each site. The farmers implemented the RWH&C demonstrations, with close support from the research team in managing and monitoring the trials, including recording various measurements, which are described in this chapter.

Farmers who were introduced to the concept of RWH&C were also involved in cross visits to sites where RWH&C is being applied to gain a better understanding of how these systems function. Two farmer-to-farmer sharing events were conducted between farmers in Muden and Ntshiqo, where farmers shared lessons learnt.

To inform some of the specific objectives of the research, the following activities were conducted.

3.3.2 Approach to evaluate current levels of productivity in crop and rangelands

Initial surveys at the project sites, which were conducted between June 2013 and June 2014, employed a participatory approach, making use of semi-structured interviews and FGDs in face-to-face meetings with crop farmers, livestock owners and traditional leaders.

While much anecdotal information was obtained from these participatory research approaches, the lack of proper record keeping required a more thorough approach to determining productivity. As a result, annual surveys of crop yields were conducted with eight farmers who were not participating in the rainwater harvesting demonstrations. These surveys were conducted for the 2013/2014 and 2014/2015 growing seasons. For livestock productivity, monthly surveys of livestock numbers, births, deaths, sales and the use of inputs was recorded from April 2014 to June 2016. This data was used to determine the baseline productivity for crop and livestock at the research sites.

3.3.3 Approach to select RWH&C techniques and determine water productivity in croplands

Selection of RWH&C techniques

The research approach to select the RWH&C techniques to be tested and the parameters to be evaluated is detailed below. The process involved identifying the best suited techniques and then workshopping the options available with the farmers to select specific practices to be tested at the research sites.

Based on the possible rainwater harvesting interventions identified in the literature review, a number of techniques were identified as having potential for application at the proposed project sites. A process was followed to consider what techniques were best suited for use at the demonstration sites. The available options were then workshopped with farmers who selected their preferred practices.

Field management

Contours in the trial sites were marked using dumpy levels and line levels. Rainwater harvesting ridges were established using locally available machinery and implements. Ridges in the treatments sites were placed at three metre intervals and rows of maize were planted on each side of the ridge (rows were approximately 1 metre apart with an intra-row spacing of 0.22 m, giving a plant population of 30 000 plants per hectare). This gave a catchment:storage ratio of 2:1 (i.e. 2 m of catchment area supplying two rows of maize 1 m apart).

Prior to planting, soil samples were taken and submitted to the Cedara laboratory for soil fertility analysis. The recommendations were used to inform fertiliser application across the treatment and control plots to exclude variation due to fertility. Land preparation was performed using locally available tractors and implements and financial support was provided by the project.

Data collection

Yield parameters

To evaluate crop yields in the treatment plots, three double maize rows (i.e. above and below contour) were randomly selected for harvesting. To obtain the area of each harvested row, the length of each row was measured. The breadth was measured by measuring the half the distance to the two adjacent rows on either side. For the control plots, three 5 x 5 m quadrats were marked and the yield from these quadrats was determined.

The sampling procedure involved counting the total number of plants within the area measured, and from that 10% of the sample was harvested. The samples were analysed for grain and biomass yield by measuring wet mass of all samples, which were subsequently oven dried at 75°C for 48 hours and measure dry matter yield was measured. Cobs were separated from parent plant and were stripped off for the determination of grain yield. The mass of stalk and leaf material were also weighed to obtain a dry matter biomass yield to determine the fodder yield for livestock.

Soil water content (SWC)

Soil samples were collected to measure gravimetric moisture content (GMC) at different depths (10, 20, 30, 60, 90 and 120 cm) depending on the soil depth for that particular site. For the treatment, sampling was performed at three positions namely: runoff area, above the ridge and below the ridge (Figure 3.6). Samples were taken at planting, establishment, vegetative growth, tasselling and at harvesting. The model output included the soil water content. After running the model, the observed and simulated soil moisture at different growth stages were compared. The growth stages were numbered as shown in Table 3.4.

.

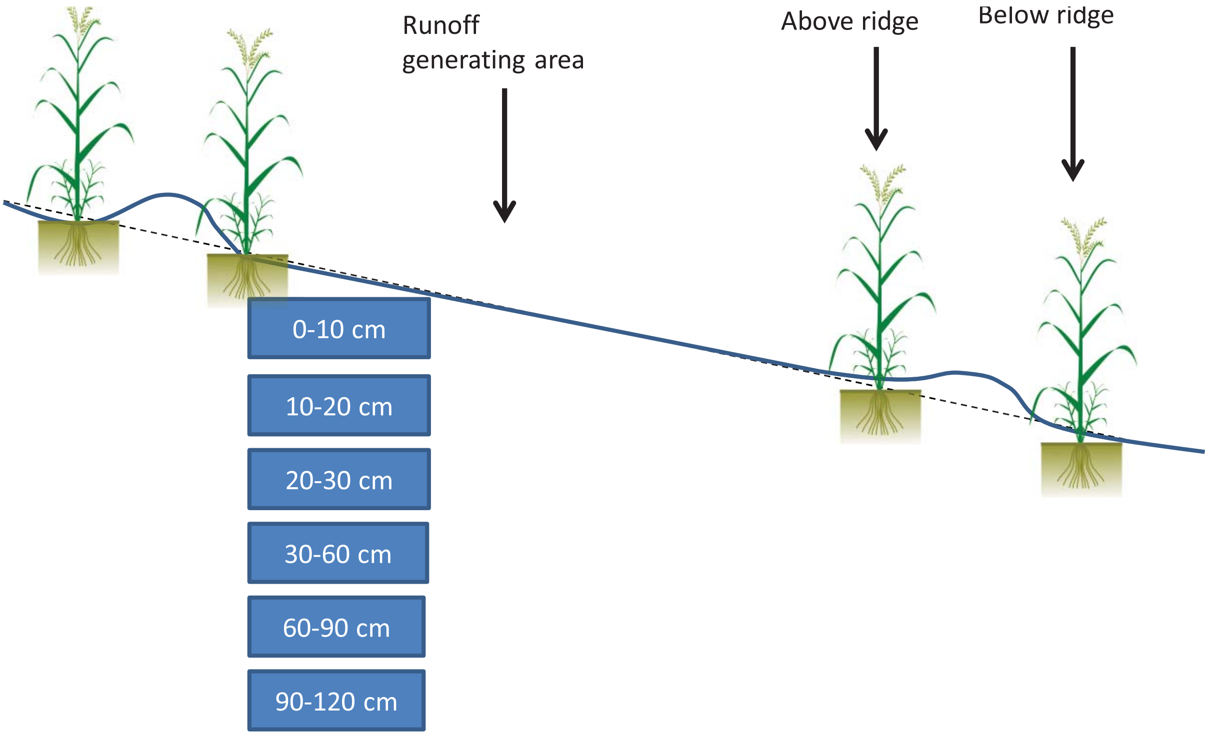


Figure 3.6: Soil sampling procedure for gravimetric moisture content at different positions of a rainwater harvesting setting

Table 3.4: Growth stages and descriptions

Number	Corresponding growth stage
1	At planting
2	End of establishment
3	End of vegetative stage
4	Silking and tasselling
5	Harvesting

Weather data

For Ntshiqo, the weather information was obtained from the Tsolo Automatic Weather Station. At Muden, Campbell Automatic Weather Stations were installed in December 2014 at both Mxheleni and Fabeni.

3.3.4 Crop modelling

The AquaCrop model, developed by the Food and Agriculture Organisation (FAO) was used to derive water productivity for the cropping demonstrations. The AquaCrop concept is based on the mechanism of crop growth where the crop canopy develops and transpires in exchange for biomass production. The root system deepens into the soil profile and takes up water. At a certain phenological stage, part of the biomass is partitioned to the yield component as determined by the harvest index (HI). Figure 3.7 illustrates the calculation process used by AquaCrop. This schematic calculation indicates that throughout the crop cycle, the amount of water stored in the root zone is simulated by calculating the incoming (rainfall and irrigation) and outgoing (runoff, ET and deep percolation) water fluxes at its boundaries. The level of water depletion in the root zone determines the extent of the water stress coefficients (Ks) affecting (i) green canopy cover (CC) expansion, (ii) stomatal conductance and hence transpiration per unit CC, (iii) canopy senescence and decline, and (iv) the harvest index (HI). Each of these effects has its own threshold depletions and response curves. Aboveground biomass (B) is derived from transpiration by means of the normalised water productivity (WP*). At the end of the crop cycle, yield is calculated as the product of the simulated B and the adjusted (HI) (Reas et al., 2009)

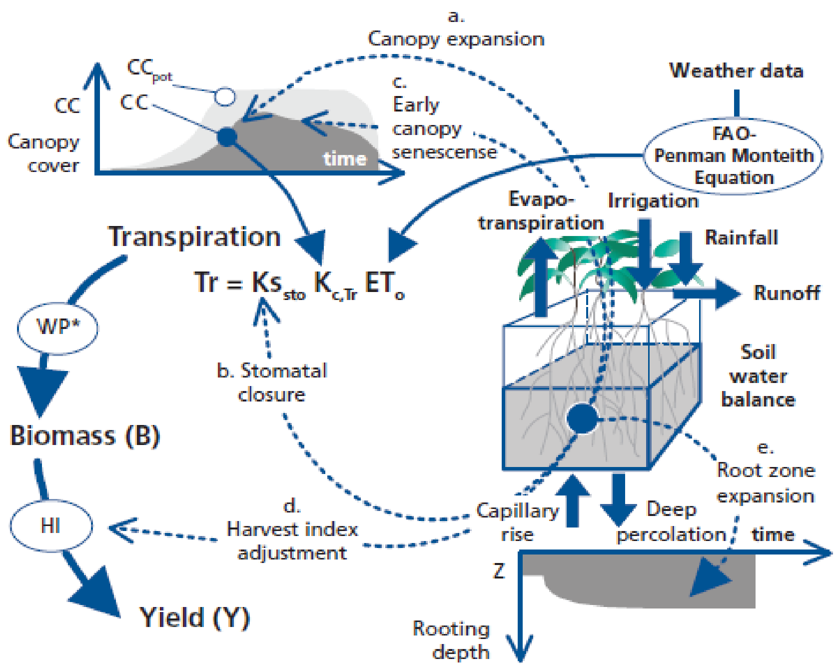


Figure 3.7: Schematic representation of calculations adopted by AquaCrop, with dotted arrows showing the processes affected by water stress. CC is canopy cover, HI is harvest index, WP is water productivity, normalised for ETo and air CO_2 concentration (Adopted from Reas et al., 2009).

In order to "RUN" the model, the input data required include climatic data, crop characteristics, soil and management characteristics. This information aids in defining the environment in which the crop will develop (Reas et al., 2009). The model uses algorithms and calculations to model water infiltration, drainage of water out of the root zone, canopy and root zone development, evaporation and transpiration rate, biomass production and lastly yield formation.

Climate file

Site 1: Ntshiqo

The climatic data utilised for this site were obtained from the ARC weather station at Tsolo. The daily climatic parameters such as minimum and maximum daily temperature (Tn & Tx), reference evapotranspiration (ETo) and rainfall were prepared on the Notepad file and fed into the model to create a climate file.

Site 2: Muden

Weather stations operating with Weatherlink software were installed at Fabeni and Mxheleni. The weather stations recorded climatic data on per hour, per day basis. These weather stations were installed in December 2014, however, the trials began in 2013, therefore climate data from the closest South African Sugar Association (SASA) weather stations was utilised for 2013.

Crop file for RWH&C and the current practice

Maize is one of the major agricultural crops for which the FAO calibrated non-location but crop specific parameters and provides the parameters as default values on the model. These parameters are called conservative parameters, meaning they do not significantly change with time, management practices or geographical location (Reas et al. 2009). With respect to crop production, the model uses normalised water productivity (WP*) to simulate yield and biomass and the harvest index (HI) used is from literature. Instead of leaf area index (LAI) the model uses canopy cover (CC) which is a function of soil surface covered by the canopy and canopy expansion. Canopy expansion requires i) plant density, ii) soil surface covered by an individual seedling at 90% emergence, iii) maximum canopy cover under optimum conditions and the canopy growth coefficient (CGC). The last three parameters are however conservative. The other important parameters that the user needs to specify are time of sowing and maximum root depth.

In the context of this research, plant density was adjusted to match the plant density observed in the field when creating the RWH&C crop file (Figure 3.9). The maximum canopy cover was assumed to be maximum (85%) because of the double maize rows along the contours and good germination observed. There is a 2 m empty space between contours, however, no parameter/feature on the model is able to account for that. Whereas on the control crop file, the plant canopy cover was assumed to vary between 'very thinly covered' (40%) and 'fairly covered' (75%) depending on the visual observations.

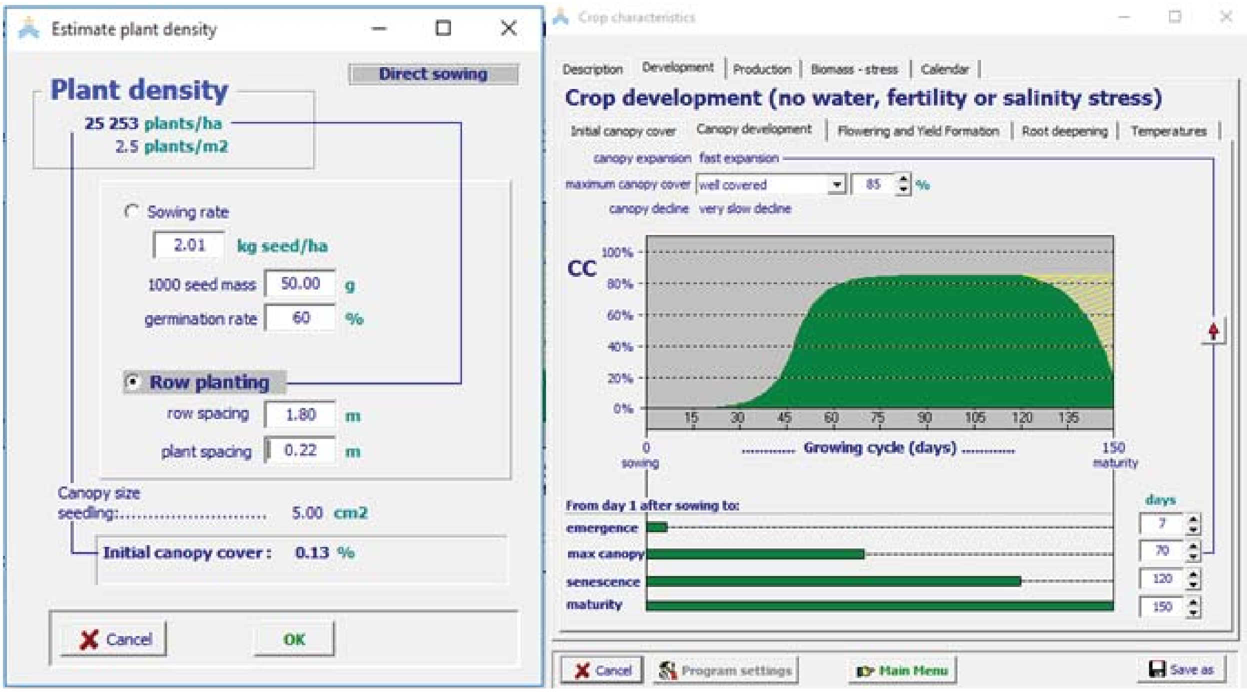


Figure 3.8: Plant density and canopy cover estimates for the AquaCrop crop file.

Figure 3.9: Plant population and field arrangement on an RWH&C setting at Muden, KwaZulu-Natal.

Figure 3.10: Plant population and emergence on the current practice setting at Muden, KwaZulu-Natal.

Field management file

The model consists of two categories of management, namely 'general' and 'specific to irrigation management'. Therefore since this research was undertaken under rainfed conditions, the general field management practice was selected. This category consists of the choice of soil fertility levels and practices that affect soil water balance. The practices include mulching and soil bunds which are built to store water in the field.

In order to bring the concept of RWH&C into the model, the treatment file specified that there were 0.3 m high soil bunds and hence no surface runoff occurrence (Figure 3.11). Whereas for the control treatment file there were no soil bunds and hence there was possibilities of surface runoff.

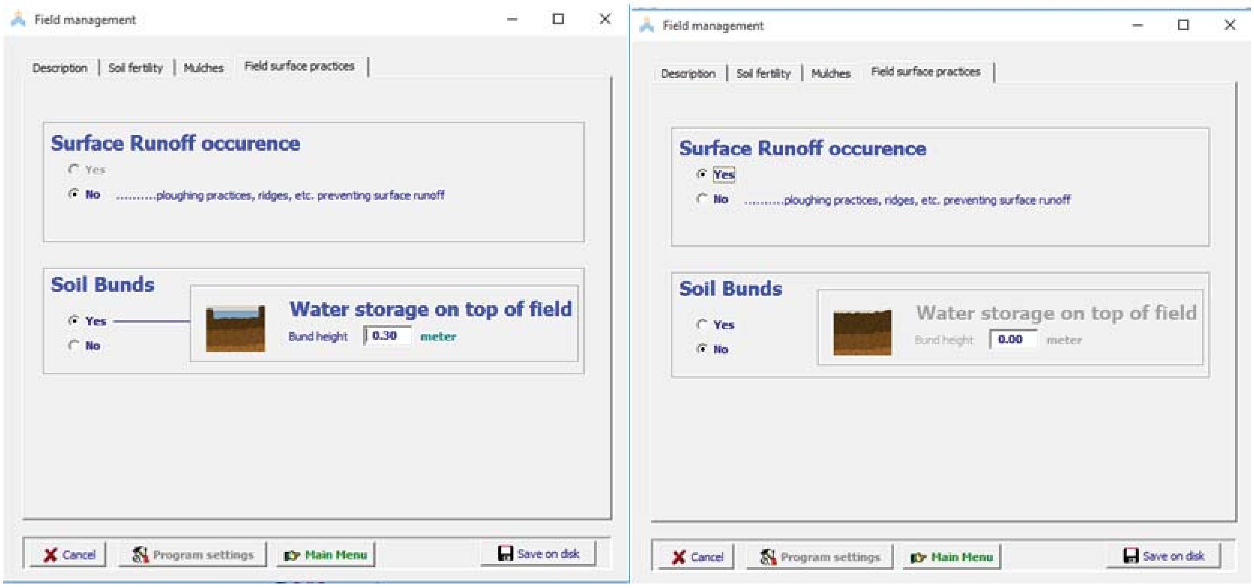


Figure 3.11: AquaCrop field management commands adjusted to simulate RWH&C and current practices.

Soil files

The important soil parameters include permanent wilting point (PWP), field capacity (FC), saturation (SAT) and saturated hydraulic conductivity (Ksat). Efforts to measure these parameters were made. Undisturbed samples were taken from each site across the soil profile and submitted to the Soil Science laboratory at University of KwaZulu-Natal. However, due to the long waiting list and shortage of equipment, the results from these samples were not received. Basic soil classification was performed at each site to determine texture and hence the indicative values for the soil parameters were adopted from AquaCrop. In terms of the soil file, there were no distinctions made to differentiate between the treatment and control.

3.3.5 Water productivity research within rangelands

Discussions with the community and expert input from the reference group concluded that the focus of water productivity research in the rangelands should be on grazing management and related strategies rather than activities that would result in soil disturbance in the rangelands, which is supported by information from the literature review as the most appropriate intervention as the rangelands were not severely degraded (see 2.4.3).

3.3.6 Demonstrations in rangelands and livestock water productivity

The focus of rangeland interventions was on those that do not result in significant disturbance of the soil. Initially interventions that spread and distribute runoff to allow greater infiltration were considered. However, it was ultimately decided to focus on rangeland and livestock management techniques that would increase rangeland productivity, since physical RWH&C techniques can result in significant disturbance to the soil, which would also result in undesirable impact on the natural vegetation, for example the introduction of weeds and invasive alien plants where the soil has been disturbed.

Due to the nature of the experiment (where the interventions are not being undertaken at a scale that allows for herds of animals to be maintained within the treatments for the duration of the trial), it was not possible to make any direct measures of changes in livestock performance as a result of the water harvesting interventions. For this reason, it was decided to rather measure changes in plant (fodder) biomass that resulted from the interventions.

Research was initially conducted at both research sites, however due to the severe drought that occurred in Muden, the effect of the demonstration interventions could not be determined and consequently, reporting focusses on the Ntshiqo research site in the Eastern Cape.

The data collection involved both quantitative and qualitative methods. The quantitative aspects included the fieldwork such as veld condition assessments, implementing exclosures and rotational resting schemes, disc pasture meter readings, grass clippings, global position system (GPS) data collection and supplemental feeding. The qualitative component encompassed FGDs for added insights, which complemented the quantitative results.

Fieldwork

Numerous techniques or procedures were utilised in the fieldwork, namely veld condition and species composition; selection of exclosures and marked grazed areas; GPS data collection; a rotational resting experiment; monthly disc pasture meter readings; grass clippings and a supplemental feeding experiment. These were conducted for the purpose of achieving research objectives 2 and 3. These procedures are described in detail below.

<u>Veld condition and species composition</u>

An assessment of species composition was conducted to determine the veld condition of specific areas. Two methods were used, namely the Levy Bridge (Fidelibus and MacAller, 1993) to obtain species composition, and the Benchmark Method (Marx, 2011; Tainton, 1981) to obtain veld condition scores.

In Ntshiqo, both methods were utilised before the final research sites were decided upon. Five pilot studies were conducted to determine the spread of veld condition across the entire grazing area in the community.

<u>Selection of exclosures and demarcated open areas</u>

Due to the continually overgrazed state of the veld in the Ntshiqo community, exclosures (these were fenced areas of specified size that restricted livestock access) were implemented to test the effect of rest on veld condition. According to Camp (1997d), periods of absence within a grazing cycle in a season, are inadequate to restore the vigour of plants lost during grazing periods. The only way to restore vigour of veld, especially palatable species, is to provide long term or full growing season rests (Camp, 1997d). Therefore this experiment was conducted to observe changes in biomass production (quantity) and quality of forage over a period of 17 months (June 2014 - October 2015). The data from the exclosures simulated a long term rest.

After considering the five pilot studies, three final sites were selected for conducting the research. The entire grazing area was divided into three areas namely site 1, site 2 and site 3 according to their respective veld condition scores (best, medium and worst respectively) obtained from species composition (Figure 3.12). In each respective site, three 5 x 5 m exclosures were erected using 1.2 m high bonnox fencing. This was done to increase the number of samples to achieve statistically acceptable results. Additionally, three corresponding open 5 x 5 m grazed areas were marked in each area. The aim was to compare the condition of the grass in the exclosures to open access areas that were not rested in terms of biomass production (quantity) and feed quality over a one-year period, hence accounting for seasonality.

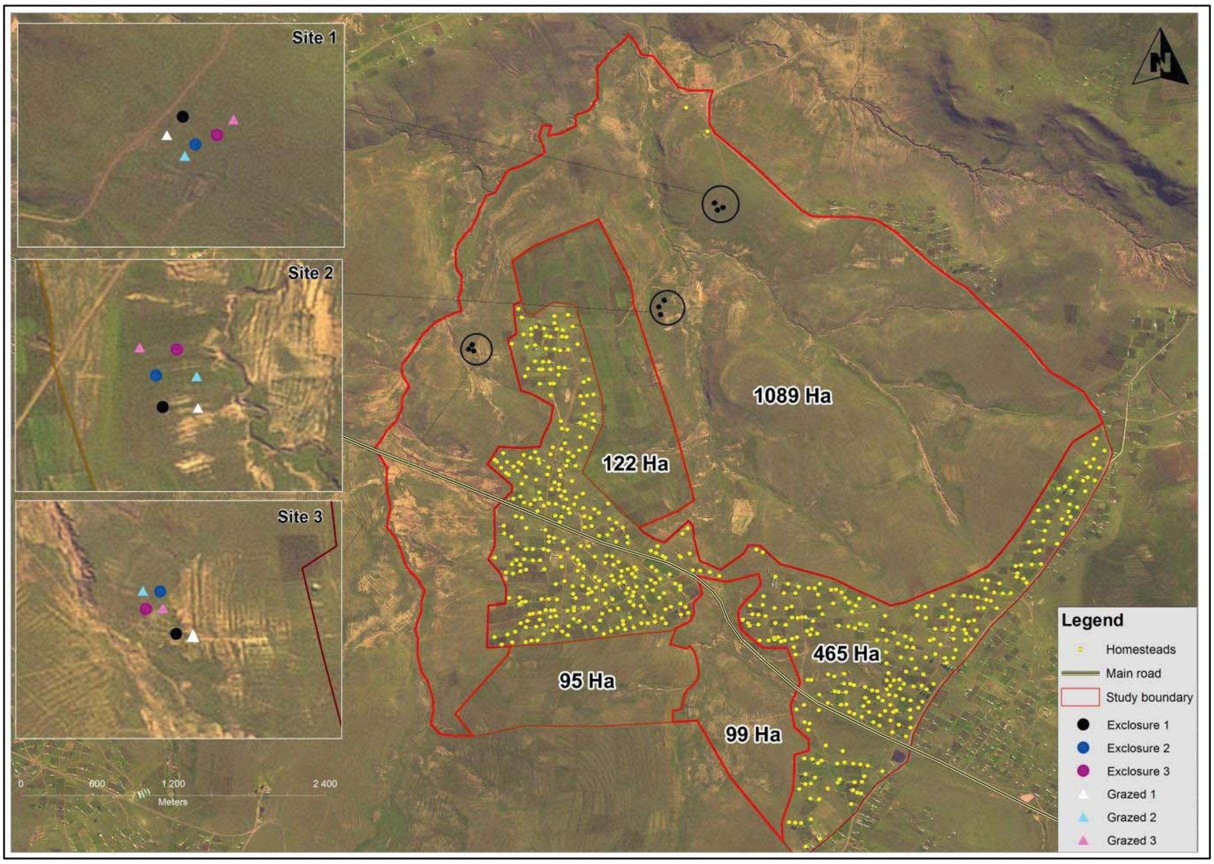


Figure 3.12: Depiction of the exclosures and grazed areas for Sites 1-3 in Ntshiqo, Eastern Cape.

<u>Rotational resting</u>

Resting of veld is the most neglected of all the important principles of grazing management in rangelands (Camp, 1997d). Rotational resting experiments propose that veld should receive a full season's rest once every four years (Smith, 1997). Generally a quarter of the veld is rested, with the remainder available for grazing. This allows veld an uninterrupted time of growth and recovery, which can improve the vigour of grass tufts.

In Ntshiqo, after numerous meetings with local livestock owners and traditional authorities, an area was selected for a rotational resting experiment. This had the same aim as the exclosure experiments, however, was conducted on a larger scale. A 90 ha area was selected for the purpose of introducing a summer rest. This specific area was selected based on veld condition assessments and knowledge provided by local inhabitants. The area had the best veld condition and highest percentage of palatable species. Hence resting this area was seen as an opportunity to potentially improve biomass production, feed quality and vigour of grass species. The area was divided into two similar halves, with Area 1 (41 ha) rested for a short period (October 2014 - January 2014) and Area 2 (48 ha) rested for an entire growing season (October 2014 - June 2015), which equated to 4 and 9 months respectively (Figure 3.13). Three 5 x 5 m marked grazed areas were selected for each half to monitor the above variables. In addition, 15 disc pasture meter (DPM) readings were taken for biomass comparisons in these marked open areas on a monthly basis for the duration of the rotational resting experiment. No fencing was implemented to separate the specific grazing areas. This was done for two reasons: firstly it was logistically unfeasible, and secondly to test the effectiveness of management systems in Ntshiqo, in controlling livestock movement. Marked stones, roads and river beds were utilised to demarcate the rested areas. Four local community members were selected as rangers by the livestock working group (LWG) to monitor the rested area and prevent any livestock from entering over the entire growing period. Integrating technical interventions with local institutional management structures and policies, promotes success of such interventions (Amede et al., 2009).

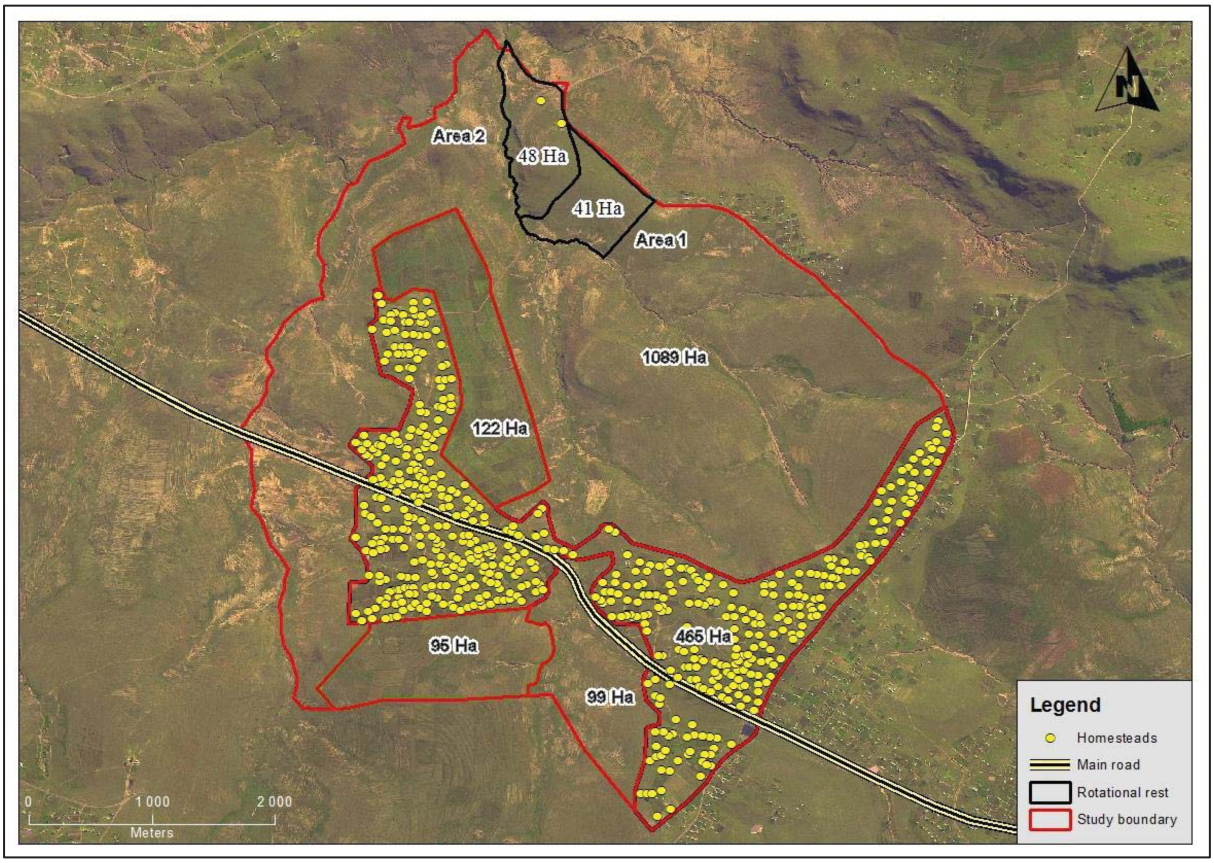


Figure 3.13: Depiction of Area 1 and 2 of the Rotational Resting Experiment in Ntshiqo, Eastern Cape.

Disc pasture meter readings

For this study, monthly biomass readings were taken in the exclosures and corresponding marked grazed areas, to compare biomass production over an eighteen month period. The disc pasture metre is a simple, inexpensive instrument which is used to make rapid estimates of standing biomass. This provides an efficient representation of biomass alterations in response to seasonality.

A total of 15 monthly DPM readings were taken, within each of the 3 exclosures and corresponding marked grazed areas, for the 3 respective sites. This allowed for the comparison of biomass production between the exclosures and open access areas over a one and a half year period. The same procedure was followed for the larger rotational resting areas for the duration of that experiment.

Grass clipping

Grass clippings were obtained to observe biomass production changes in relation to seasonality. This aided the analysis of the feed management component of the LWP framework for the purpose of achieving research objective 2. This was done to illustrate potential positive effects of resting veld and to encourage smallholder farmers to implement similar systems, potentially on a larger scale.

In Ntshiqo, grass clippings were obtained for calibration purposes in relation to monthly biomass readings. Three clippings were taken in each exclosure and in the corresponding marked grazed areas of identical size at each site (Figure 3.12). The clippings were obtained in February 2015 which represented summer, June 2015 represented winter (after the first frost) and October 2015 represented spring. Clipped samples were dried and used to construct a calibration graph by plotting dry weight ($t.ha^{-1}$) against the related pasture metre disc readings (cm). This allowed for the construction of biomass accumulation curves with the influence of seasonality.

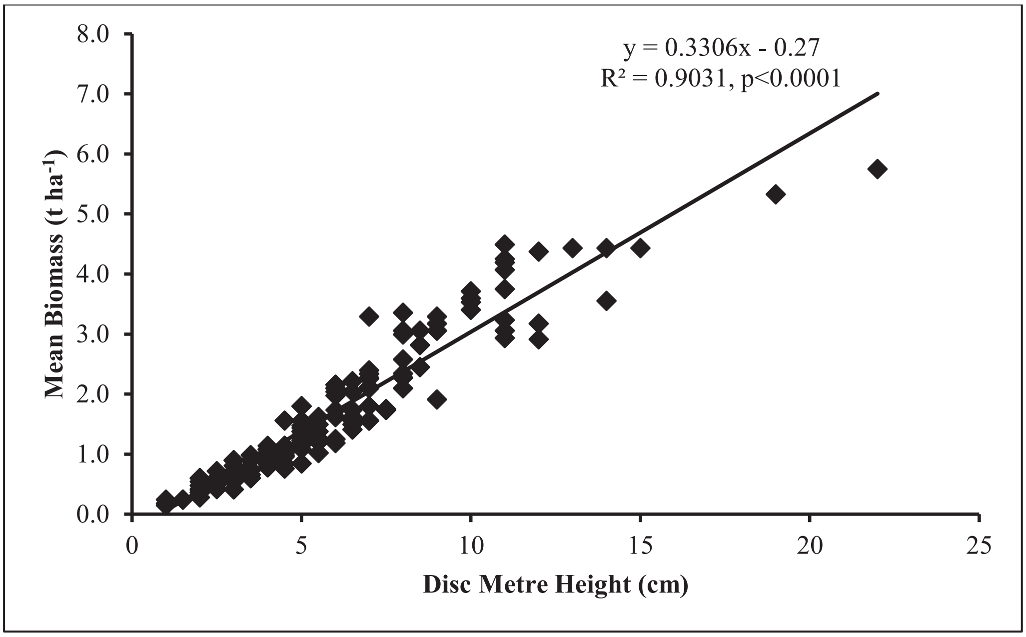
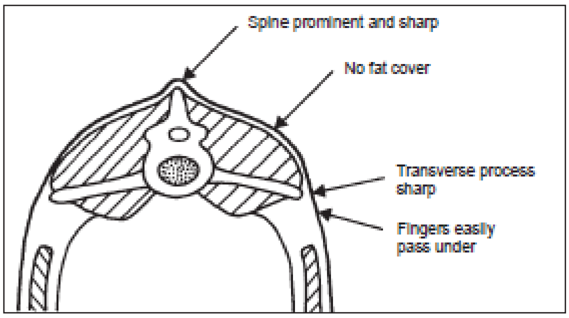


Figure 3.14: Combined calibration graph (n=162) illustrating Disc Metre Height (cm) and Mean Biomass (t ha^{-1})

Supplementary feeding

The lack of supplementary feeding poses as a major constraint to livestock production in sourveld regions of South Africa (Van Niekerk and Jacobs, 1985; Israel and Pearson, 2000). A supplementary feeding experiment using protein licks was conducted for sheep to determine how this would affect productivity, based on body condition scoring. Voermol Protein licks were provided to the sheep over the winter period of June to September 2015. A total of 54 sheep that were being fed (treatment) were condition-scored and 50 without access to supplementary feeding (control) were scored. This condition scoring technique ranged on a scale from 1 to 5 (Figure 3.15 to Figure 3.19). Half scores were utilised if animals were in-between condition scoring categories (Suiter, 1994; Thompson and Meyer, 1994).



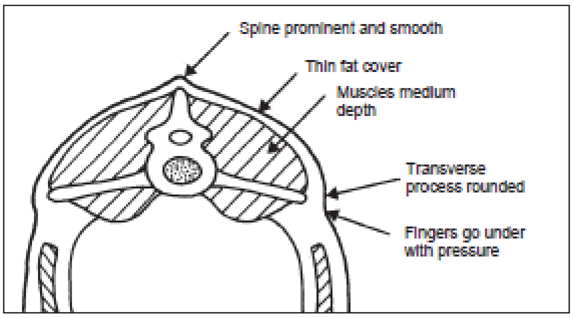
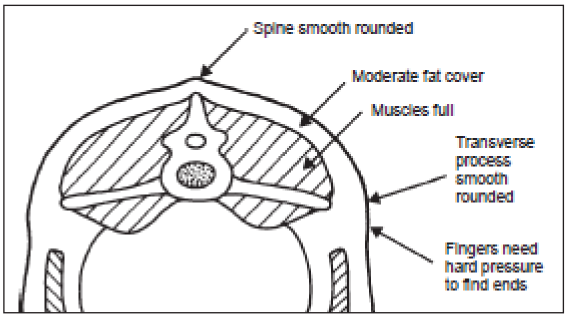


Figure 3.15: Body Condition Score 1 (Emaciated); Figure 3.16: Body Condition Score 2 (Thin)



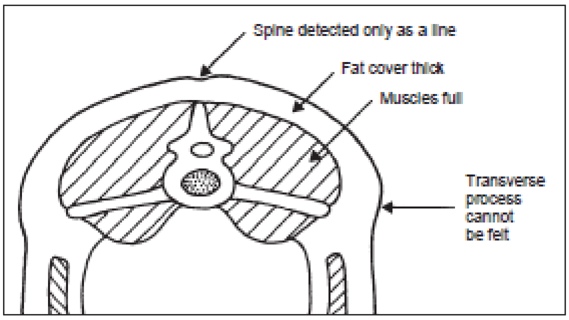


Figure 3.17: Body Condition Score 3 (Average); Figure 3.18: Body Condition Score 4 (Fat)

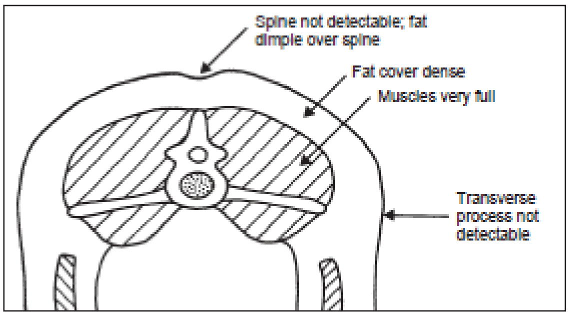


Figure 3.19: Body Condition Score 5 (Obese)

Fodder crops (vetch and oats)

The planting of fodder crops was introduced to the farmers participating in the RWH&C cropping trials in Ntshiqo. This was done for the purpose of determining how a winter fodder crop in a homestead garden could contribute to livestock productivity, and to inform smallholder farmers of techniques to increase the quality and quantity of feed for livestock during winter. Four smallholder farmers who were involved in the RWH&C demonstrations participated in the fodder demonstrations.

A mix of vetch and oats was intercropped as a winter fodder with the RWH&C demonstrations. Vetch and oats were selected according to a few criteria: firstly they are both winter growing crops which have the potential to address forage shortages in winter. Secondly they were identified as the hardiest winter fodder crops and could grow well with little management. These fodder crops excelled at the demonstration sites.

3.3.7 Interviews and focus group discussions

Detailed structured livestock questionnaires were administered to livestock owners to understand current levels of animal productivity. These questionnaires aimed to identify current management systems and did not show the benefits of the rangeland management interventions per se, but provided a good understanding of the livestock production system and productivity of livestock. They were administered on a monthly basis to households with varying livestock numbers. This was done to observe differences in livestock management and to provide important information on herd structure and livestock productivity. They considered calving/kidding rates, mortality rates and offtake of cattle, sheep and goats through sales, slaughter and other cultural uses. Furthermore, the questionnaires monitored the use and dosage of medicinal products given to livestock and prevalence of supplementary feeding. These questionnaires were outside the scope of the current research focus but the general findings were utilised to provide insight and to inform the results obtained. Through the formation of the livestock working group (LWG), FGDs were administered. This incorporated the qualitative component of the research.

3.3.8 Data analysis

The data analysis comprised laboratory results, GIS-related data, qualitative data obtained from FGDs, documentation and statistical analyses. The laboratory analysis involved drying grass samples and sending them to Cedara Laboratory in KwaZulu-Natal for full feed analyses. Important data obtained from the FGDs were used to support the quantitative results. Statistical analyses were conducted for the resting (feed quantity and quality) and supplementary feeding experiments. The statistical analyses were conducted in Microsoft Excel 2010, through the Data Analysis application, accessed by activating an 'Add-in' known as Analysis Toolpak. This provided data analysis for statistical and engineering analysis. Under data analysis, numerous statistical tests were provided, including paired t-tests and independent t-tests.

3.3.9 Research for RWH&C in relation to adoption and outscaling

Ntshiqo

Individual interviews, workshops and FGDs were conducted with farmers participating in the trial, their neighbours (who had observed the trials but did not participate), and a representative of the local traditional authority. The purpose of the interviews was to identify opportunities and constraints to the adoption of RWH&C. The responses to questions sought to understand social, institutional, cultural and economic factors that influence the adoption of RWH&C. Project evaluation workshops were conducted with livestock owners and crop farmers at the end of the project to evaluate lessons learn and requirements for outscaling and upscaling.

Muden

Given that there was crop failure in Muden due to the severe drought, the research team sought to understand what would be required for outscaling by evaluating constraints to production and potential solutions. Individual interviews were conducted with farmers participating in the RWH&C experiments. Seven respondents were interviewed. This was followed by a FGD attended by 17 farmers including farmers participating in the experiments, neighbours who had observed the experiments and three young people who are actively involved in livestock and grazing management structures. Project evaluation workshops were conducted with livestock owners and crop farmers at the end of the project to evaluate lessons learn and requirements for outscaling and upscaling.

4 DYNAMICS INFLUENCING ACCESS TO COMMUNAL CROPLAND AND RANGELAND

This chapter discusses the social and cultural dynamics as well as the institutional and organisational arrangements at the two research sites. Information to inform this chapter was gathered through engagement with local traditional leadership, the provincial departments of agriculture and meetings and interviews with community members.

4.1 Institutions and organisations playing a role in land access and use

There are three organisations which play a direct role in supporting the people at both sites as far as land use and access, cropping and livestock are concerned. These are the traditional authority itself, the local municipalities and the local Departments of Agriculture.

The local municipalities play a role in the provision of services and maintenance of infrastructure. The municipality, through its councillors, also facilitates the provision of social services, such as assisting residents to access social grants, pauper burials and the registration of births. The Municipalities' role in land allocation and managing land use in communal tenure land is extremely limited.

The local Departments of Agriculture provide extension support to farmers. The Departments assist with the provision of tractors for land preparation and the provision of some agricultural inputs. They also provide advice on crops to be grown and other agricultural matters, but have little say on how land is allocated.

The traditional authority facilitates and manages access to and the use of land in the communal tenure land in Ntshiqo. They are by far the most important role-player in this regard and the systems for the Eastern Cape and KZN are discussed separately below.

4.1.1 Eastern Cape (Ntshiqo)

In the Eastern Cape there are at three recognised Kings. The people of Ntshiqo, who are *Mpondomise*, fall under the fourth king and are still negotiating for his recognition. Prior to 1994 there was a period where traditional leaders were abolished in the Eastern Cape, as there was the belief that under the new government they would not be necessary under the new constitution. However, later the constitution did in fact recognise traditional leadership.

An organogram of the traditional structures in Ntshiqo and, by extension, the Eastern Cape is provided in Figure 4.1.

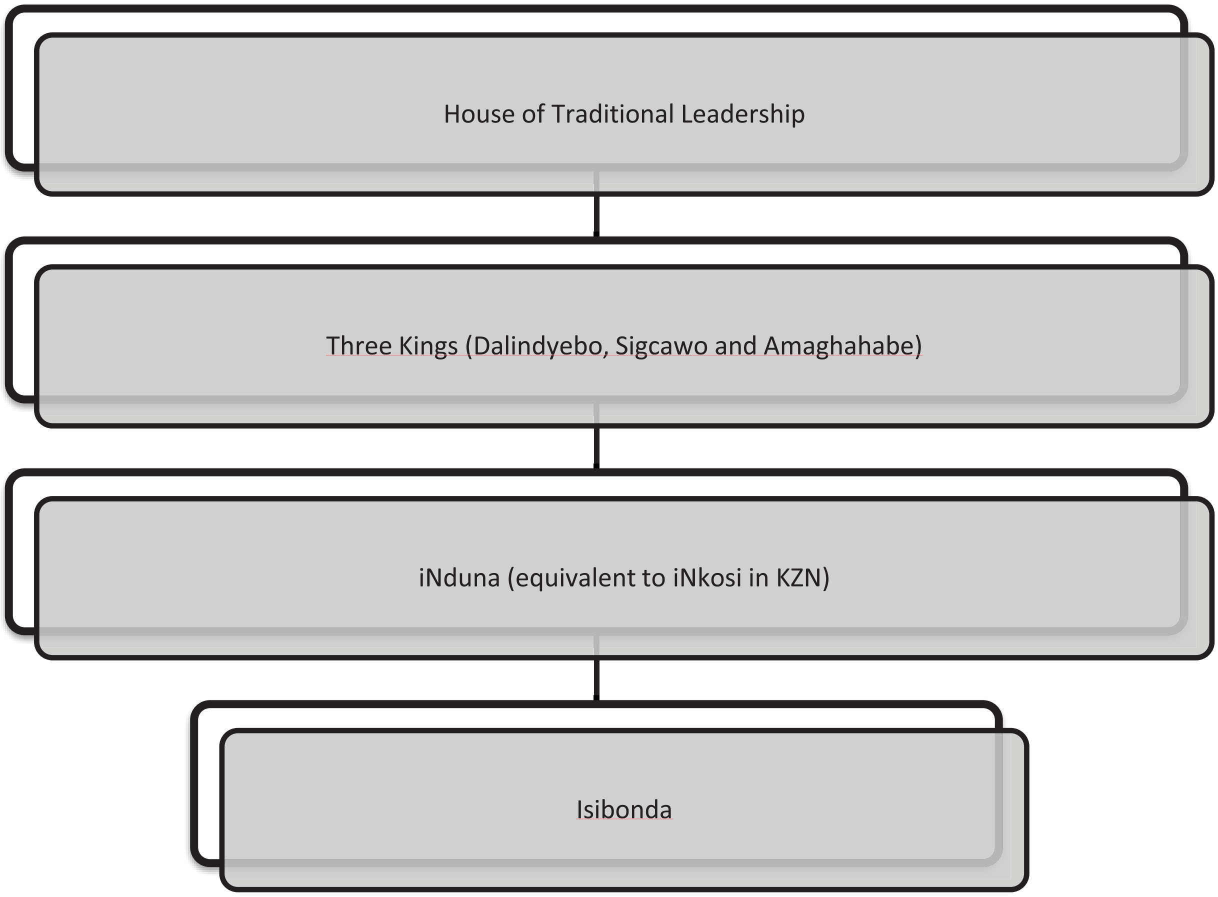


Figure 4.1: Overview of Traditional Leadership structures in the Eastern Cape, focussing on Traditional Authorities in Ntshiqo

In Ntshiqo the Induna is the equivalent of the iNkosi in KZN. In the Eastern Cape, the induna is the final arbiter in matters relating to land use and land allocation in communal tenure land.

4.1.2 KwaZulu-Natal (Muden)

All traditional leaders fall under King Zwelithini ('*iNgonyama*' – 'Lion' or 'King') who is the sole trustee of Ingonyama Trust, which holds all communal tenure land in KwaZulu-Natal. At a District scale in KwaZulu-Natal, there are nine District Traditional Councils, one for each District Municipality in the Province. The Traditional Leaders in The Muden – Msinga area fall under the Umzinyathi District. Within Msinga Local Municipality, there are six amaKhosi (chiefs – See Figure 4.2).

The three Muden research sites fall under iNkosi Mchunu. He is the leader on all matters pertaining to traditional leadership within his realm and this area is called Machunwini, or 'place of the Mchunu clan'. iNkosi Mchunu is assisted by iNdunankulu Zakwe (Chief induna and advisor to the chief). Within the chief's jurisdiction, there are 11 iziNduna who are responsible for specific isigodi or wards. Each iNduna is assisted by a number of iPhoyisa who are elder, respected community members who act on the iNduna and/or iNkosi's behalf at important family or community ceremonies, for example, umemelo (girls' coming of age) and umshadu (wedding). Their role is also as primary peacekeepers and resolvers of minor conflicts. There are usually two to four iPhoyisa per isigodi, each responsible for a given area.

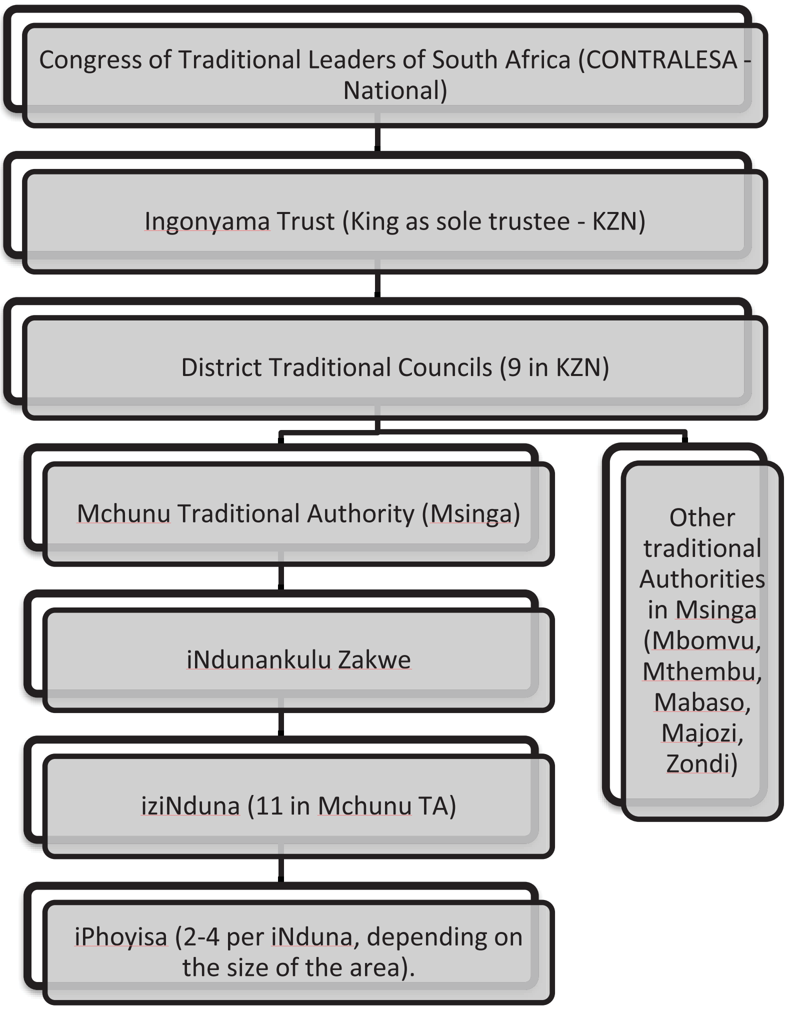


Figure 4.2: Overview of traditional leadership structures in KZN, focussing on Mchunu Traditional Authority in Muden

4.2 The process of land allocation

Traditional authorities play a key role in the land management and land allocation in Ntshiqo in close consultation with the community. The Ntshiqo area, much like most of the Eastern Cape was subjected to betterment planning in the 1960s and 1970s. The intention of this was to stabilise and increase agricultural land by formally subdividing communal areas into residential, arable and grazing areas (Gqokoma, 2005). This resulted in a landscape where there were discrete clusters of homesteads that have their own homestead gardens along with larger arable fields occurring either close to, or some distance from, the homestead. The average size of the fields allocated to farmers in Ntshiqo is one hectare. While this is sufficient for mainly subsistence production, the land limitation, in combination the lack of technical support for production means that it is extremely difficult for most farmers to produce enough food for subsistence purposes, never mind commercial production and sale of produce (Gqokoma, 2005). In Muden, there was no betterment planning and consequently, homesteads are scattered across the landscape, rather than concentrated in certain areas.

4.2.1 Residential land

The processes for allocating residential land in Ntshiqo and Muden are discussed separately below as there are some important differences.

Ntshiqo

In Ntshiqo, respondents indicated that there is still residential land that is available and not allocated to anyone. When acquiring land in Ntshiqo, it is first necessary to verify whether this land has been allocated to another household, which requires discussion and consultation with local community members. If the person is from within the community, they can identify the land they would like to use, consult with residents and go straight to the chief to request the land in question. If a person is from outside of the community, it is necessary to have a connection with a person who is already staying in the area, who may be a friend or a relative who would take this person to the chief.

If the land has not been allocated to anyone, then the negotiations are escalated to the traditional authority. Where land has already been allocated, the applicant would first engage with the land 'owner' to determine if they will allow the applicant to have some of their land allocated to them. If both parties agree to this, then they jointly approach the traditional authorities.

When it comes to the responsibility of land allocation, all respondents indicated that this lies with the Chief. Once the land has been identified and it has been confirmed that it has not been allocated, the applicant would approach the Induna, who would present the applicant to the chief. The Chief asks for the specific location of the site in which the applicant is interested. After this, the Chief sits down with the land allocation committee to confirm that the land is not owned by anyone and can indeed be allocated to the applicant, after which the land is allocated.

As far as payment is concerned, a 'vote of thanks' is made to the Chief to seal the transaction. Opinions differed on what this entailed. One respondent indicated that an amount of R1 000 is paid by a person who is a citizen of Ntshiqo who is moving to a new site, but a person who is not a citizen of Ntshiqo has to pay an amount of R3 000 to access land. Another respondent indicated that no formal payments were necessary, but that the applicant should provide catering for those who bear witness (usually local community members and representatives of traditional authorities) to the event, as a gesture of good will.

Muden

In Muden, a new person who arrives in an area or an individual from the area ('applicant') who is looking for land would approach a neighbour (in the case of the a new arrival) or family member (in the case of a local person coming of age and wanting their own land) to assist and act as a facilitator ('sponsor') in securing land. The sponsor would then call nearby neighbours together and present the applicant's intent to request land. Once the neighbours have accepted the request, the applicant will be presented to the iNduna. The iNduna will then present the applicant to the iNkosi. During this process, a background check on the applicant will be conducted to ensure that they have been a good resident and have not caused unnecessary trouble or been a bad influence. The background check would include information from people who know the applicant. Often a letter from someone in a leadership position in the area that the person came from is also required to confirm that the person left the area in good standing. Once this approval process has been finalised, land will be allocated to the applicant, who will be reminded of the major rules and responsibilities arising from this land allocation. Residents recognise that they are not owners of the land, but are land users and subject to the rules and regulations associated with being a land user.

Usually, the iNkosi will concur with the residents' approval or refusal of permission. The iNkosi does have the right to veto the community's decision, but the iNkosi has never compelled any community to accommodate or refuse someone without their approval.

The first entry point to land access is the establishment of the house or homestead. Without this, a homestead cannot qualify to graze or farm in the area. Within the defined homestead area, a land user may build homes, bury family, harvest resources (e.g. firewood) and grow crops. Homesteads are often located close to each as they are concentrated near to water resources and other infrastructure (e.g. roads) and have common boundaries that are often not clearly defined which can be a cause of conflict.

When an applicant is planning to build or farm on land that is unsuitable, that person is discouraged from using that land. For example land may be unsuitable because it is rocky, making it difficult to build and to bury family members.

The approach outlined above indicates that the process for allocating land is largely a social one, where consensus regarding the allocation is built from the bottom up, with a number of steps in the process whereby land allocation can be refused. This also acts as a form of social control to help to ensure that residents' behaviour is conducted according to accepted norms and values.

4.2.2 Cropping fields

In Ntshiqo, there are large areas of arable land that have been fallow for some time and are available for farmers. The process for securing arable land is the same as for securing residential land. An applicant would first approach the local residents to determine whether the land has already been allocated and to whom. If the land has been allocated to someone, the farmer would enter into negotiations with the land holder to have this land re-allocated or to lease the land. Whatever agreement is reached in this regard, the proposal is taken to the chief for verification and approval. In cases where the land has not been allocated, the applicant would first notify the local landholders and, subject to their approval, would take the application to the chief.

The process for cropping fields in Muden is similar to the process in Ntshiqo. However there is a general scarcity of arable land and consequently land users are reluctant to give up their use rights to the arable land.

4.3 Perceptions of land ownership

Land holders in both Muden and Ntshiqo indicated that they felt either that they themselves, or their family, 'owned' the land. One respondent stated that 'we got this land from the chief and we can utilise it the way we want to – you can see that we divided it into cropping land and the house that you can see here'. Another stated that 'yes, we do own land – we can use it for planting crops and building houses - I would say that this land is our homeland'

Another respondent indicated that the use rights and rules for land in rural areas are developed by the citizens of the area. Rules for this include curfews (the time after which people should not be walking around after dark) and boundaries of livestock grazing areas. This respondent also pointed out that the municipality can only arrange rules and rights for people living in urban areas as these areas belong to the municipality, while rural areas are ruled by the traditional leaders. This sentiment highlights that there a clear sense of separation of powers between the rules for rural and urban landscapes in Ntshiqo.

In Muden, iNdunankulu Zakwe and his advisors in Muden recognised that the land belongs to King Zwelithini (As the sole trustee of the Ingonyama Trust). Traditional authorities, including iNkosi (Chief), iNdunankulu (Advisor to the Chief or Head Induna) and iziNduna (Indunas or local leaders) manage communal land on behalf of the King. While the King plays a figurehead role, land issues are dealt with exclusively by the local traditional leadership structures. As far as perceptions of ownership are concerned, iNdunankulu Zakwe pointed out that that the Ingonyama Trust protects all communal land in KwaZulu-Natal from people wishing to claim the land and that the amaKhosi are the caretakers of the land on behalf of their residents or subjects.

Of the land under the leadership of a particular iNkosi, two broad ownership elements are recognised. The iNkosi 'owns' iZwe, which is the total area of jurisdiction under a particular iNkosi, while iNdawo, on the other hand, refers to smaller parcels of land that have been allocated to specific individuals or families, along with certain rights (i.e. iZwe refers to the bigger picture, while iNdawo refers to specific parcels used for settlement or cropping. One group of respondents likened it to a loaf of bread, where the loaf 'belongs' to the iNkosi, while individual slices belong to residents). There is therefore recognition that while an iNkosi has powers over all the land under his jurisdiction, there are also specific individual / family user rights which exist and are protected through traditional law.

The dominant view of respondents regarding perceptions of land ownership was that they recognised that the land has been allocated to them by the traditional authorities and that they reside and make use of the land at the will of the people and their leaders. They further recognised that, should they make serious transgressions, they stand to forfeit their land use rights. However, as far as tenure security is concerned, land users felt very secure regarding the land that had been allocated to them and believed that they and their descendants will have continued use of the land allocated to them into the future.

4.4 Gender dynamics

4.4.1 Land allocation

When asked about gender and land allocation, respondents (mostly male) at both Ntshiqo and Muden stated that the process of land allocation is consistent. Even when it comes to gender, respondents felt that there was consistency.

In Muden*,* iNdunankulu Zakwe indicated that the procedure of obtaining land for women was the same as it was for men and that new traditional rules had been established to be in line with the constitutional imperative of gender equality. The rule states that both men and women should have equal access to land. As the discussion at this meeting progressed, however, it became apparent that gender played an important role in land allocation. One respondent stated that ‘it is never easy to allocate land to a woman as the she can easily be claimed by some man and that land will automatically change hands’. This statement highlights the on-going dominance of patriarchal thinking and its influence on gender equality. There was general agreement that it was necessary for a woman to be accompanied or represented by a man when requesting land.

In Fabeni at Muden, it was noted that it would be difficult for a woman to obtain land without some form of male participation. If her husband has passed away, or there has been a divorce, there must be a male child on whose behalf she is holding the land. An example was made where a man’s sister returned to her family’s area due to a failed marriage. She could not secure land without the support and participation of her brother.

Text Box 4: Observation of allocation of land to a woman

While Mr Malinga was conducting interviews he had the opportunity of observing the allocation of a piece of land to a widower. At the site that had been allocated were the woman's in-laws (i.e. deceased husband's parents) who were representing her. The positioning of the various parties was also telling. The women sat separately from the men, while Mrs Madondo (the applicant) sat alone, far apart from everyone. Her brother-in-law acted as the intermediary, who shouted to her the decisions that had been made regarding the boundaries of the homestead. When questions were asked of her, the brother-in-law again shouted questions at her, to which she had to respond. It was stated that the household would be named Madondo - the surname of the deceased husband.

When all present had agreed to the allocation of the land for her homestead, several male elders started to give her instructions and warnings against bad behaviour. She was told to be open with her in-laws and the neighbours about the men in her life as they wouldn't like to see different men queuing or any young women losing a husband to her. The neighbours stated that they didn't expect to lose chickens or other small items as a result of her arrival, indicating that they trusted her. The Ndunankulu closed the meeting by telling her that he has never had to have any mediation meetings with people in this neighbourhood and he doesn't want do so in the near future. After closure all the neighbours offered help in anything she might want.

Much of the process observed shows that there are strong patriarchal influences, for example, the husband's family representing Mrs Madondo. However there is also an important message for Mrs Madondo that she should not act in a manner contrary to accepted norms and standards to maintain social cohesion. Finally, neighbours indicated that they trust her and offered support. While parts of the process may seem harsh and sexist, the message seems clear: work within the rules and behave appropriately and you will be part of the community and be assisted.

In Ntshiqo, one respondent commented that in the case of women, there would be a process determining your potential 'risk' to the local community (in terms of for example, being a woman who is a threat to cultural norms and values). Some enquiries into their marital status and other questions aimed at discerning their suitability would be asked. Another respondent at Ntshiqo did state that if women are applying for land they should be accompanied by a man, who ideally should be a family member. People are, however, suspicious of women who are not from the community looking for land and it would be very difficult for such a person to access land without having good references.

One woman who was interviewed confirmed that the process and procedures that are followed are the same irrespective of the gender and that everybody has equal rights to access land. She stated that 'I am the only female that applied to access the land when my husband was away working places in Gauteng; it was easy for me to be allocated the land since they knew I am married.’ The fact that she was married seemed to carry weight in the decision that was made, which indicates that gender remains a factor in land allocation, given that marital status seems to be a factor in deciding whether or not it is appropriate to allocate land.

Another respondent pointed out that there are cases where women from this community married someone from elsewhere and settled with him. In cases where a woman has to return home, such as in the case of death or an end to the relationship, they do have the right to come back and ask for new land to access. These women cannot go back to their family homes as they have been married, but considering this, the process is consistent for both men and women.

Thus, while it is perceived by mainly male respondents who were interviewed that women have equal opportunities in accessing land, the responses indicate that women are at a disadvantage when it comes to this.

4.4.2 Involvement of gender in livestock and cropping

In Ntshiqo, sheep and cattle make up the greatest numbers in terms of livestock ownership. Some goats are kept mainly for cultural purposes. Ownership and herding of cattle, goats and sheep by women is frowned upon. However, there are incidences where this will occur. Pigs also are commonly kept in in Ntshiqo and these are owned and managed by women.

When it comes to tending and managing crops, this is the responsibility of women. Women are responsible for watering, weeding and hoeing of crops. Men are responsible for the tillage of the land, particularly where draft animals are concerned – women are not allowed to hold a plough or to control a span of draft animals. In some cases, work in the field is distributed equitably among family members.

In Muden, ownership and herding of cattle by women is also forbidden. However, there are incidences where widows will herd and manage cattle. These women are allowed to break the rules, but are excused labelling them as a bit ‘dilly’ due to the loss of their husband and should not be further upset by being told that they are not allowed to do this, when in fact everyone knows that they are simply disobeying the rules and do not care. It is often difficult to challenge a woman directly, particularly if she is a widow.

A telling statement by one respondent captures both the patriarchal views on gender and at the same time highlights the importance attached to land. When asked whether he had land in the irrigation scheme, the response was ‘I have land in the irrigation scheme – eight plots. I also have dryland fields. I treat them equally, just like a man with many wives; the lands receive equal love and care from me.’

4.5 Resolution of conflicts

Disputes commonly arise over livestock (related to ownership and to livestock destroying crops), land issues and conflicts between adults and young men fighting over girls. Some conflicts are considered more urgent than others and these should be resolved as quickly as possible. The movement of livestock in croplands appears to mainly be an issue within dryland cropping areas close to where livestock graze. Livestock movement within the irrigation scheme at Muden is tightly controlled due to the high value placed on the crops that are grown there.

The process for resolving conflicts, including land conflicts involves a 'bottom-up' approach. Where conflict occurs, the first step is to attempt to resolve the conflict at a family or homestead scale through discussion, in the hope of reaching a compromise or agreement, depending on the nature of the conflict. If the conflict cannot be resolved by the relevant family or families, then neighbours are commonly called in to witness and act as mediators. In some cases, adult men will come together and talk about a cause of the conflict, but resolution usually requires that the issue be taken to the iNduna or isiBonda (in KZN or EC respectively) who will call the parties together to resolve the issue. If the issue cannot be resolved by the iNduna / isiBonda, the resolution will be escalated to the iNkosi.

Respondents did note, however, that the process outlined above has declined in recent years as there are fewer recognised elders and they are not accorded the same respect as in previous times. As a result, conflicts are often not properly resolved and reappear.

4.6 Rules and rights for different types of land use

Three different land use areas are recognised at both Ntshiqo and Muden. These are the homestead, the arable lands and the common property communal grazing area. These elements are discussed in more detail below.

4.6.1 The homestead

The homestead is the primary land where use rights are allocated to an individual or family. In Ntshiqo, homesteads were established in clusters during the betterment schemes, although residential areas have expanded over time. Landholders feel very secure regarding their tenure within the homestead. Main activities associated with homesteads are:

- The building of homes – these must be approved by neighbours and the surrounding community.
- Burial – family members may be buried in the homestead. In Ntshiqo, elaborate graves built of brick, concrete and granite are often observed in the homestead garden.
- Grazing and kraaling of livestock, especially when livestock need to be kept close to the homestead.
- Cultivation within the homestead garden – this usually consists of a designated area for vegetable production (isitiye/ izala), which is protected from livestock and watered as well as an area for grain, mainly maize production (igadhi/ ingadi).

Children who grow up and intend building their own homesteads on the family land should inform the broader community before proceeding. Given the concentration of homesteads as a result of betterment schemes, it is often the case that families seek a new place to settle elsewhere as the boundaries of the homestead area cannot be expanded. Homestead land cannot be traded or sold.

Text Box 5: Illegal sale of land for imizi

Within Msinga, an example was made of where an iNduna had been illegally selling land for homesteads near to the main road (there is a demand for property close to the road). This became obvious when many homesteads were seen to be cropping up near to the road. After a preliminary investigation by the iNkosi and iNdunankulu, the iNduna concerned was suspended and an acting iNduna appointed in his place. After a period of some months, the case is still pending. There was general consensus among people discussing the matter that the case would probably not be pursued, through the legal or traditional justice system, but that the iNduna would be quietly side-lined and the acting iNduna would be formally appointed. While this may seem to be a light sentence, it needs to be borne in mind that 'iNdunaship' is often passed on in the family and as a consequence of these actions, this family now has no future iNduna and has lost standing in the community – another example of the role of social control systems within the Traditional Authorities.

4.6.2 The cropping fields (*amasimu*)

Cropping fields in Ntshiqo are larger than homestead gardens. These lands have been planned and are clusters of one hectare units that are farmed. Historically, a large number of fields were cultivated, but the extent of cultivation has declined over time. Fields that are the farthest from the residential areas are most likely to be abandoned first due to distance and difficulty in preventing livestock entering the fields during the growing season. Due to the lack of control of grazing by livestock, farmers have withdrawn to fields that are closer to home and also cluster their fields. This allows crop growers to cooperate in controlling livestock, reduce fencing costs and also keep an eye on each other's fields. Grouping together also means that the crop farmers also have a stronger voice when lobbying for crop production issues at community meetings and for ensuring that when livestock do transgress, there is group support when taking a case of livestock transgression to the traditional authority.

In Muden, fields are located wherever arable land can be found, as this is limited in this area. Fields are protected by fences. In many cases, cropping lands are clustered together, although this is not always the case. The reasons for clustering include the following:

- Good arable land is often concentrated in one area and therefore has to be shared among local residents.

- Cropping land is often isolated which means that there is a higher risk of theft and potential danger for women working alone on the lands, which is another reason for clustering.
- Clustering increases efficiencies and reduces costs and labour, for example it is cheaper to have one fence around a larger area than many fences around smaller areas.

Such fields are often ‘owned’ by a family group and extended family members have access to these lands.

Where land has been designated for cropping, the building of homesteads is not allowed. A land user can plant and harvest any crops on the cropping land allocated to them.

While individual user rights exist during the crop production season, the fields become a common property resource in winter. This is an important issue as it limits the extent to which farmers are willing to invest in their lands. For example, cover crops could be used for winter fodder and soil improvement, however the broader group of livestock owners would benefit from this as livestock graze the fields and is thus a disincentive to manage the land more productively.

4.6.3 Rules for abandoned or fallow land (fields)

Arable fields cannot be sold, but can be leased from other farmers or re-allocated. There are extensive areas of arable land that have been abandoned in the Ntshiqo area. This is attributed mainly to the lack of control of grazing livestock in summer. There are large tracts of adjacent arable grazing lands, some of which are closer to the homestead and some of which are some distance from homesteads. Respondents maintain that arable fields that are far from the homesteads have mostly been abandoned. Farmers have consolidated their land holdings closer to the homesteads. With the arable lands concentrated in a relatively small area, and being closer to the homesteads, farmers are better able to control livestock access and also work together in controlling livestock access.

In terms of accessing abandoned or fallow land, it is first necessary to determine whether or not that land has been allocated to anyone. If it has already been allocated, the applicant would need to enter into negotiations with the current landholder to determine if any interest remains in farming the land. If the current land holder is no longer interested in using the land, the applicant can approach the chief and have this land re-allocated to them and confirm the exchange. If the land has not been allocated to anyone, an applicant would approach the chief directly. However, in most cases, landholders are reluctant to cede user rights to the land allocated to them and would rather lend or lease the land to others. Again, once the terms have been agreed between the land holder and the applicant, this would be reported to the chief so that he is aware of the agreement between the two parties. Rental costs were not provided, and cash rental is not common. In most cases, in-kind contributions (i.e. a portion of the harvest) are provided instead of cash, although in other cases there may be other terms, such as free use until a family member returns from working elsewhere to farm the land.

4.6.4 Common property (amadlelo)

The common property resource includes all lands not allocated to homesteads and cropping land. Old croplands that have reverted back to primary succession grasslands are considered common property. Key resources that are common property include:

- Water – all water is common property and it is unusual for a homestead area to include a water resource, although it may be a boundary. While water is a common property resource it is prioritised for household use (drinking and washing). Currently there is a project to supply piped water to homesteads in Ntshiqo, but many homesteads, particularly on the outskirts of the homestead areas obtain water from springs and streams.
- Collection of firewood – in Muden, only dry wood may be collected. Green wood may not be harvested. In addition fruit bearing trees, such as Marula, Wild Plum and Red Ivory may not be harvested. This rule applies to all community members, but by default applies to women, as they are the ones who harvest firewood. This again highlights the gender-specific allocation of duties. In Ntshiqo, which is grassland dominated, there is little firewood available. In some cases, cattle manure is used for fuel. Many of the houses in Ntshiqo are electrified, or in the process of being electrified.
- Harvesting of thatch.
- Harvesting of medicinal plants and other natural resources.
- Grazing of livestock – this is discussed in a separate section below.

4.6.5 Rules related to livestock

Livestock play an important role at both sites. In Muden, cattle and goats are the main types of livestock that are kept. Goats outnumber cattle by a wide margin in the area as all households have goats, but not all households have livestock. Additional reasons for higher goat numbers, when compared with livestock are that (1) from a management perspective goats are easier to manage due their smaller size and are more resilient to disease and drought and (2) the valley bushveld that occurs in Muden is dominated by *Vachellia* (Acacia) trees, meaning that there is much browse available to goats and (3) goats tend to produce more offspring (twins are common). Furthermore from a cultural perspective, women and even children are permitted to own goats, while the ownership of livestock remains the realm of men. In some cases, such as a widowed household, women do own cattle inherited from the deceased head of the house.

Herding

In Ntshiqo, the grazing area for livestock is relatively small and has been demarcated based on agreements with residents of neighbouring communities. During betterment planning, livestock camps were established with fences and rotational grazing was practiced in the area. However, over time, the fences have gone and without the herders, there is little control of grazing. Livestock owners also commented that lawlessness has increased and theft of fencing and livestock is a big problem. In summer cattle graze everywhere, except for fields where they are kept out by fences. In winter, livestock are allowed to access cropping field to graze on crop residues.

In Muden, livestock grazing areas and boundaries are demarcated by mutual agreement between residents of each *isigodi* (ward). It is the responsibility of herders to ensure that livestock remain within the designated grazing areas.

Herding at both sites was traditionally the responsibility of young boys who would herd the cattle and who would be in serious trouble if they allowed livestock to move beyond the specified boundary, either purposefully or accidentally. However, young boys are now schooled and no longer have time to herd livestock. In Muden, herding of livestock is still regarded as a boy's job and adult men who herd livestock are considered lesser men (like 'boys') as they are performing a task which is beneath them. Consequently there is a situation where livestock simply are not herded, but wander around looking for grazing with little control over their movements.

In the past there were rules about where to graze livestock and rotational grazing was practiced. However, as respondents point out, "no one follows those rules now as we don't have boys to herd the livestock as before. In summer our cattle now graze everywhere, it's only in winter where we sit down as farmers and plan when we are going to open up the gates to our harvested fields to provide fodder to livestock".

Thus, a situation has emerged where the rules are, in theory, still in place, but that a new set of rules (requiring the education of boys) has meant that the herding rules can no longer be implemented. While there are people who are potentially available to herd livestock, cultural values discourage grown men from herding livestock. There is thus a 'herding vacuum' exists in which livestock are not properly controlled.

Competition between crop and grazing land

In Ntshiqo, there is a large proportion of land that is arable, when compared to grazing land. Within the designated boundaries of the grazing lands for Ntshiqo, there is little grazing when compared with cropping lands. This has led to a competition between grazing animals and people who use the land for crop production. Farmers have noted that as control of livestock has diminished – both through a lack of herders to manage livestock, as well as the loss of fencing, there has been increasing abandonment of arable lands, which has increased the proportion of land available for grazing. This sometimes leads to conflict within the community.

4.6.6 Discussion about rules and rights

The process for land allocation in Ntshiqo and Muden are very much a bottom up processes whereby local consent is first obtained and then is approved by the traditional authorities. A similar process applies for circumstances under which land can be refused or where a person is banished, although it appears that this is very rare. As far as security of tenure is concerned, community members interviewed feel very secure in relation to the land that has been allocated to them and do not seem to fear losing their land. This perception of security applies to both the homestead and the cropping lands.

While there is a perception (particularly among men) that women have equal rights in terms of accessing land, this process requires the presence of and sponsorship by a man, preferably a family member, before the land allocation process can be agreed to and approved. This indicates that the land allocation process, in terms of gender, is not equitable.

There are also clearly defined gender roles regarding livestock and cropping. The handling of cattle, and sheep (in Ntshiqo) is largely the realm of men, while women tend to the pigs, which are commonly kept in Ntshiqo. In Muden, women handle goats, but not cattle. As far as cropping is concerned, men are responsible for land preparation and planting, while women's roles in are largely in weeding and tending the crops. Given that most of the land preparation is now done using machinery, the men's role in the land preparation has become limited organising and supervising machinery for land preparation.

The resolution of conflicts is also a bottom up one. Resolution is first attempted with neighbours, or the aggrieved party, after which it escalated to headman then onto induna in the case of serious conflicts.

The rules of the different types of land use (homestead, crop lands and common property) in Ntshiqo were modified quite drastically as a result of betterment planning in the 1960s and 1970s and these rules stand today. Rules for land use are maintained through social controls and supported by Traditional Leadership, with the community playing a central role in maintaining the rules. Similarly, in Muden, the community plays a central role in maintaining the rules and ensuring censure for disobeying the rules. However many older respondents note that the extent to which the rules are followed has decreased in recent time. It was also pointed out that as distance from the Traditional Authority's (iNduna and iNkosi) homestead increased, influence decreased and there is less adherence to the rules. So, while there are social controls to maintain the rules, the traditional leadership clearly plays a role in maintaining control and enforcing rules.

Many respondents at both sites noted that there has been a trend of increasing lawlessness, which relates both to criminal activities (e.g. theft) as well as an increasing disregard for the traditional rules governing land use and allocation within Ntshiqo. The declining observation of rules was raised as a concern a number of times by respondents. Increasing lawlessness in terms of criminal activity was attributed to lack of prosecution of accused parties. Respondents also acknowledged that fewer people are adhering to traditional rules, particularly younger people.

At both sites, there is a rule, in theory, that land fallow for three years or more can be re-allocated, this does not occur in practice. Firstly because there are large areas of fallow land (mainly in Ntshiqo), there is little competition for arable land and secondly, most landholders are unwilling to relinquish land allocated to them as they anticipate that children or other family members may want to use this land in the future.

There is limited control of the movement of livestock, which means that a continuous grazing system dominates. This system does maximise livestock numbers, but is relatively poor for livestock productivity – limited grazing for livestock means that there are lower rates of conception and weaning by livestock. The lack of control of livestock movements has resulted in the abandonment of arable lands and crop farmers clustering together to reduce risks associated with livestock damage.

Traditional governance structures in Ntshiqo are still well established, although there are indications the rules and local norms have been eroding in the recent past, although traditional leadership does remain important. The rules regarding land allocation in Ntshiqo are maintained by the Induna and the land allocation committee, which is headed by the Induna. The approach to managing land allocation is very much a bottom up consensus building approach, rather than a top-down autocratic system. This inclusive approach applies both to conflict resolution and securing access to land. Municipal councillors have limited influence and control on land and related matters in Ntshiqo.

Landholders in Ntshiqo and Muden perceive their tenure to be very secure and that they and their family will have access to their land in perpetuity, as long as they abide by the user rules associated with that land use.

4.7 Overview of livestock and crop systems at the project sites

4.7.1 Ntshiqo

Arable fields are made up of blocks of 1 hectare. Farmers who are still actively farming use their land for the production of maize, which also the primary crop in homestead gardens. Historically farmers would intercrop with beans and pumpkins in their fields, but with the introduction of subsidised maize production through the state massification projects where glyphosate tolerant maize is used in conjunction with herbicides, intercropping no longer occurs. One farmer pointed at that they now only plant maize in their fields since they are not allowed to intercrop in the project that they have joined (See Text Box 6).

Text Box 6: The Massive Food Production Project (MFPP)

The MFPP was implemented in 2003 by the Eastern Cape DRDAR in response to declining agricultural production. The perceived reason for the decline in production was the lack of modernisation of agriculture and the programme aimed to improve food security through mechanisation of production. Farmers are subsidised with a grant that decreases incrementally over five years. The main commodity being promoted under this programme is maize (Mtero, 2012). The grant and loan system is managed by uVimba finance, which is a division of the Eastern Cape Rural Finance Corporation (ECRFC), an organ of the Eastern Cape DRDAR. The ECRFC's objective is to finance projects in the rural areas of the Province.

Farmers in Ntshiqo participating in the scheme were reliant on the provision of machinery by the Department for land preparation and planting and were also provided with seed and fertiliser. Farmers have raised concerns that they are paying R1 800 per hectare, to participate in the scheme, with the balance of costs being financed though uVimba. However, farmers have no control of when planting occurs. For example in the last growing season, planting by service providers contracted by the Department only occurred in January, meaning that farmers participating in the scheme were not able to harvest any crops. uVimba finance, however still expected the balance of costs for establishment to be paid back.

Homestead gardens range in size from 0.1 ha to 0.5 ha, but are usually 0.3 ha in extent. Maize is also the main crop grown here, but in addition to maize, farmers often intercrop with beans (mainly sugar beans) and squashes (mainly pumpkins). Other important crops in homestead gardens are potatoes, sweet potatoes and butternuts.

In addition to the staple crops, vegetables are also grown by some farmers in designated areas (isitiye) within the homestead gardens. Here a variety of vegetables are grown in summer and winter. Important winter crops are peas, cabbages, carrots, spinach in winter and in summer green beans, tomatoes, onions and spinach, which are used for own consumption. Fruit trees are also often planted in homestead gardens (e.g. peaches, plums and apples)

Farmers were asked what triggers or indicators they used to start planting. Most farmers indicated that they plant in November, while one farmer stated that he plants in September. In some cases where rains are late, farmers plant in December. November is the main month for planting as this coincides with the onset of the summer rains. Some farmers indicated that they wait for the rain before planting while others plant in November irrespective of rainfall. One farmer pointed out, importantly, that it was the availability of a tractor to plough the land that determined when planting would occur.

Inputs for crop production

Land preparation

Land preparation in both fields and homestead gardens is done using tractor-drawn machinery. Local tractors can be hired for land preparation, but the DRDAR also provides tractors for land preparation. The use of draught animals for land preparation is limited. Standardised rates for land preparation are provided in Table 4.1.

Table 4.1: Costs related to land preparation

Preparation type	**Cost in Rands per hectare**
Ploughing – mould board plough	1 000
Discing	750
Planting	500
Boom spray	300

Seed

Farmers who are participating in the Massification Scheme are making use of seed that is provided by DRDAR. Concerns raised by two farmers regarding this seed were that they take longer to mature and that the supply of seeds is often late. Some farmers purchase their seed from local stores (e.g. Boxer Cash and Carry, or the cooperative in Mthatha). One farmer indicated that he prefers to use hybrid seeds as they produce much better yields, while another indicated a preference for store bought seed as it is capable of performing under a variety of climatic conditions.

In their homestead gardens respondents indicated that they favour their own saved seeds over hybrids or genetically modified (GM) maize. The main reason for this preference is that farmers prefer the taste of the maize that is grown from their own seed. One farmer also pointed out that he thinks that his own saved seeds are more nutritious. As one farmer said 'I use red seed that I buy there from the project to make money, but here in my garden I use that mixed coloured seeds that we buy in the community. I prefer to use traditional own-saved seed because I know them very well when compared with the seed that we buy.'

Text Box 7: Homestead rainwater harvesting in Ntshiqo

Mr Ntamo is a small-scale farmer in Ntshiqo. He has a homestead garden as well as a field where he is practicing rainwater harvesting. At his home, he is diverting water from the adjacent tarred road into his garden. He was also diverting water from the road into a small dam off his property, which he used until recently for supplementary irrigation. This dam was removed when trenches were dug in 2013 for reticulation of potable water.

In addition to diverting water from the adjacent road, he also collects surface runoff from his and his neighbour's yard, which he stores in a cistern during summer.

He also practices micro-catchment rainwater harvesting by using ridge and furrow systems to collect and store runoff. In addition to his conventional maize production system, which includes intercropping with beans and squashes, he uses all these water resources to grow vegetables, including spinach, potatoes, and cabbage. His main cabbage crop is grown after harvesting his maize and he plants about 1000 cabbages in February, which he sells in April – May. When he has sold his cabbage crop he says he is like a man from Johannesburg – lots of money.

The rainwater harvesting systems contribute greatly to his production system, but he still has to collect water for supplementary irrigation in winter from a spring approximately 500 metres from his homestead. When the spring runs dry, he collects water from the river, which is approximately 2 km from the homestead.

Having established a humble abode at the site in 1992, the homestead has grown to five buildings and a highly productive, although small, vegetable plot. Testament to his success is that everybody knows that if you want to buy vegetables, you go iKhukwini – the chicken house: a reference to the original humble abode established there.

Furrow guiding water of the main road into the homestead (left) and open cistern to collect runoff from Mr Ntamo and his neighbours homestead (right).

Fertiliser and soil amendments

Farmers at Ntshiqo make extensive use of mineral fertilisers and farmers stated that they purchased fertiliser for their crops – in some cases, fertiliser is provided by the DRDAR as part of the massification scheme to increase crop production in the area. In addition to the use of fertilisers in both fields and homestead gardens, most farmers also make use of kraal manure in their homestead gardens to improve soil fertility.

Pesticide

Farmers at Ntshiqo are regular users of pesticides. With the DRDAR projects, glyphosate is used extensively to control weeds in the cropping fields as the maize seed that is planted is glyphosate tolerant.

The keeping of livestock

Livestock play an important role in in the Ntshiqo community from a social, cultural and economic perspective. All farmers who were interviewed keep some form of livestock.

The grazing of livestock and the use of fields

Farmers stated the two main rules for the grazing of livestock are firstly that they may not graze beyond the agreed boundaries of the designated Ntshiqo grazing area and secondly that livestock may not graze in fields where cropping is taking place. When crops are being planted, a meeting is called at the iNduna's house where it is announced that livestock should be kept out of cropping lands. Animals should be kraaled before nightfall to reduce the risk of stock theft. Respondents also pointed out that it was required that pigs be kept in enclosures (kraals) all the time and were not allowed to be walking around.

Livestock owners all agreed in recognising the importance of cropping fields as a source of fodder in the winter months – these lands are important because not only is the stover used to feed livestock, but the maize grain is also commonly used by farmers for supplementing livestock feed, particularly during times of drought.

Text Box 8: Leasing of private land for grazing of livestock

In Ntshiqo, a number of livestock owners have grouped together and leased private land near Maclear to increase grazing capacity and the number of livestock they own. The farmers pay an amount of R15 000 each per year to lease the grazing, but it has been productive for these farmers. In 2008 when they started leasing, they had 28 head of cattle. After five years they now have 69 head of cattle as a result of the livestock producing offspring.

Animal health

Respondents pointed out that DRDAR do show farmers how to raise and manage livestock. Important aspects of animal health management were regular dipping to maintain animal health and the vaccination of livestock against diseases. Livestock graze continuously in the allocated grazing area, even during periods of drought.

Collaboration with other farmers in herding and managing livestock

All livestock owners who were interviewed indicated that they collaborate with other farmers when herding and managing livestock. The following areas of collaboration were mentioned by livestock owners:

- Sharing ideas with regard to herding and managing livestock.
- Collaboration with other farmers in terms of how to keep my pigs healthier.
- Farmers also collaborate to make sure the people do not set fires and raising awareness of the need not to make fires. Farmers also collaborate in controlling fires when they do occur.
- Farmers collaborate in ensuring that livestock are kept out of arable fields during the cropping season.

4.7.2 Muden

Farmers at Muden grow maize as their primary crop. Other important crops in their fields and homestead gardens are sorghum, beans (sugar beans and Teppary beans) and squashes (pumpkins and amabhece – an indigenous traditional squash). A few farmers indicated that they plant sweet potatoes and potatoes.

While most farmers see maize as their primary crop, intercropping was also a common characteristic of many of the croplands, in particular the fields. For example the Fabeni farmers indicated that they plant maize as the primary crop, but intercrop with beans and squashes.

A common approach to cropping in dryland fields is to broadcast maize seeds over the area to be cultivated, after which the seeds are ploughed in, usually with animal drawn implements and the depth of soil turned over is relatively shallow. Tractor drawn ploughs go deeper and turn over large amounts of soil, which can reduce germination of maize. When this happens, farmers fill the gaps by hand. With animal drawn ploughs, germination is generally good (due so shallower ploughing) and once the maize has emerged and is at a four leaf stage, weeding is done using hand hoes. During this weeding process, farmers then interplant with beans and squashes.

As far as planting dates are concerned, these ranged from August to December, but most farmers indicated that they plant in November. However actual planting date is determined almost exclusively by the arrival of rain; when it arrives, farmers start preparing for planting. In some cases, farmers plant in November even if there has not been sufficient rain, because beyond this point, there will not be a long enough of a rainy season for production to be achieved.

The cropping system is well suited to the area and limits risk through the diverse crops that are planted. Maize is the staple crop, but can be prone to failure or low yields in dry years. Similarly, pumpkins do not cope well with drought. Dry beans can still produce under conditions of low rainfall. These three crops form the backbone of food security. Teppary beans and amabhece provide additional food security in times of drought as they are highly drought tolerant. According to farmers, Teppary beans do not produce many beans in wet years, but produce copious amounts in dry years. Amabhece also produce well in dry years. In good years, amabhece will often be left in the fields to be eaten by livestock, but are an important source of nutrition when times are hard. Thus, although it appears that the cropping system is a fairly simplistic one that uses low levels of technology, the combination of crops that are grown contributes to a resilient and drought resistant food production system.

Figure 4.3: Women at Fabeni, Muden carrying uchokwane (Teppary beans) home for threshing

Figure 4.4: Mxheleni women's group vegetable cropping area at Muden, KwaZulu-Natal

Inputs for crop production

Land preparation

Farmers in Fabeni who were interviewed indicated that they use draught animals (mainly donkeys) when they prepare their dryland areas – single furrow mould board ploughs are used. Farmers also use tractors from the KZNDARD when these are available, but the supply is erratic and unreliable (See).

Seed

Farmers obtain seed from three main sources, namely own-saved seed, seed bought from other farmers and hybrid seed purchased from stores. Most farmers make use of open pollinated varieties (OPV) of maize seed. This is obtained mainly from saving their own seed from the previous harvest. When there has been a poor yield and the farmers cannot save any seed for the next season, then farmers purchase own-saved seed from other farmers. This seed can also be purchased on pension days at pension pay-out points and at Tugela Ferry town.

One farmer indicated that he buys seeds from stores, but could not verify whether it was OPV, Hybrid or GM seed. iNdunankulu Zakwe, a local traditional leader pointed out that he was using different types of maize cultivars, as he gets advice from agricultural advisors who are helpful and introduce him to cultivators that are very productive. However, upon further investigation, it was found that this advice was from seed company representatives supplying seed to farmers in the irrigation scheme. Dryland farmers are generally not visited by seed or other representatives of input suppliers as their croplands are small and dispersed over a large area. The irrigation scheme, on the other is geographically dense and has farmers who can better afford to purchase inputs.

For dryland farmers the predominant seed is own saved or locally procured OPVs. Farmers prefer this seed as it is more drought tolerant and less expensive than store-bought seed.

Fertiliser and soil amendments

The use of chemical fertilisers on dryland cropping areas is limited. Most farmers use kraal manure, although usually not every year. This is attributed largely to limited availability to cover the whole field every year. When farmers notice yields are dropping they re-apply kraal manure, which can be every two to three years. One farmer pointed out that he does not use any kraal manure or fertiliser and points out that the soils is inherently fertile and good yields are obtained every year. Two farmers referred to the use of kraal manure as farming the ‘natural way’, indicating a preference for traditional production methods.

Pesticide

Only one farmer indicated that he made use of pesticides. The rest stated that they do not use pesticides.

Text Box 9: Tractors for land preparation

Interviewed farmers indicated that having tractors available to plough their land is very important to them as it saves a lot of labour and money. The KZNDARD office in Msinga has a fleet of tractors, which are provided free of charge to farmers as part of their Mechanisation Programme. There is a process for securing tractors from the KZNDARD for land preparation. Farmers or groups have to register with the Department. The process should involve a visit from the extension officer who does a survey of soil type, fertility and depth, after which they are registered on the mechanisation database. Farmers then apply to get their land prepared and are placed on a waiting list.

When the Fabeni group was interviewed some members pointed out that they have to hire donkeys from others for land preparation. When they do not have enough money, they cannot plough their lands and then rely on tractors provided by the DARD, or do not plant at all. There are at least fifteen farmers with separate fields in the Fabeni group's fenced cropping area, many of whom are very poor. They point out that when the first farmer registered, soil depth and other information was captured, but later, the application forms were simply filled in near the cropping areas with no assessments conducted.

Dryland farmers point out that they cannot rely on these tractors as they often do not arrive or arrive for a short period and do a few fields, and then leave, never to return. The farmers also notice that they see tractors driving past and when they enquire, it is apparent that these tractors are going to the irrigated lands. It is alleged that farmers in the irrigation scheme, who have more productive land and are more 'wealthy,' pay the tractor drivers (who are contracted to the KZNDARD) money to prepare their beds. As the irrigation scheme is in a concentrated area, with many farmers who have cash, the tractor drivers prefer to do land preparation there as they can secure extra cash to supplement their salaries.

When the KZNDARD was questioned regarding this, it was acknowledged that this is a problem. The KZNDARD pointed out that farmers who are not on the waiting list are the problem, as they approach the tractor drivers and pay cash to get their land preferentially ploughed. It was also noted when visiting the KZNDARD offices that there were numerous tractors that were out of commission, many with wheels missing and various other breakages. This was attributed to 'weak' tractors (65 and 90 KW four wheel drive Tractors) and that farmers were asking drivers to plough rocky areas (in rocky areas, one would imagine that the shear pins on the mould board ploughs that are used would break before the tractor did, or if the extension officers had surveyed the land properly, this risk could have been averted). This case highlights how relative power and wealth are securing benefits for those in the irrigation scheme at the expense of the 'poorer' dryland farmers. It also highlights that better governance and oversight of state resources is required. While these problems are a result of poor governance, the blame is shifted to the farmers who 'bribe the tractor drivers' or 'require the driver to plough rocky land'.

The keeping of livestock

Most farmers in Muden keep some form of livestock. All farmers interviewed have goats and many are also cattle owners. Livestock play an important role in in the community from a social, cultural and economic perspective. Grazing management involves livestock grazing relatively far from the homestead in summer, in the hills surrounding the homesteads. Winter grazing occurs closer to the homestead and in croplands, where crop residues are grazed. In times of drought, cattle are often moved to better grazing areas further from the homestead.

Goats tend to stay closer to the homestead in summer and winter, but are allowed to graze residues as well. Goats are less likely than cattle to be moved to better grazing areas in winter. Some farmers have grazing available in their fenced croplands which they reserve for winter once grazing is depleted in the grazing areas.

Farmers also recognise that in good rainfall years, production is greatly enhanced. While there has been drought in recent years, the previous year was a very good year, with cows almost producing two calves in one year. In good years, there is a lot of grass available within and outside the fenced areas and it is said that "calves are independent, there is no calf that is following its mother (i.e. they are weaned), which is an important sign of a good year".

Some farmers work together when herding and managing livestock, while others indicate that they work alone. One farmer pointed out that since children are now attending school, livestock owners have to collaborate to manage their livestock, for example if someone is sick or has to attend a meeting, someone else will look after their livestock if they are requested to do so.

As far as goats are concerned, there are more goats than cattle. Nearly all households in Muden have goats. This is because goats are not only kept by men but by all in the community including women and children. When there are temporary jobs in the community such as road construction and water installations, the money earned is invested in goats. There are some households that have more than 100 goats and participants estimate that the minimum any household would have is 15 goats.

4.8 Discussion of cropping and livestock keeping

The rules of the different types of land use (homestead, crop lands and common property) are well established and are maintained through social controls and supported by traditional leadership, with the community playing a central role in maintaining the rules and ensuring censure for disobeying the rules. In Ntshiqo, settlements and local institutions were modified drastically as a result of betterment planning in the 1960s and 1970s but the rules regarding land access and use remain similar to those of Muden, indicating that institutions remain strong and slow to change.

Older respondents in Muden noted that the extent to which the rules are followed and enforced has decreased in recent times. It was also pointed out that as distance from the traditional authority's homestead (iNduna and iNkosi) increases, there is less adherence to the rules. So, while there are social controls to maintain the rules, the traditional leadership clearly plays a role in maintaining control and enforcing rules.

Many respondents noted that there has been a trend of increasing lawlessness, which relates both to criminal activities (e.g. theft) as well as an increasing disregard for the traditional rules governing land use and allocation within Ntshiqo.

At both sites there is a rule, in theory, that land fallow for three years or more can be re-allocated, but this does not occur in practice. In Ntshiqo this is because there are large areas of fallow arable fields and thus little competition for arable land. At both sites, it seems that most landholders are unwilling to relinquish land allocated to them as they anticipate that children or other family members may want to use this land in the future.

In Muden, rules regarding the control and management of livestock have been well established and reside with the iNkosi and his council, while the iziNduna ensure that the rules are followed. For example, the iNduna will announce when it is time for livestock to graze the crop residues and when livestock have to be removed from the field to allow people to start ploughing. The dip tank committees also play a role in enforcing these rules and in promoting good livestock management, particularly from an animal health perspective.

There is limited control in relation to the movement of livestock in at both sites, which means that a continuous grazing system exists. This system maximises livestock numbers, but is relatively poor for livestock productivity – limited grazing for livestock means that there are lower rates of conception and weaning by livestock. The lack of control of livestock movement has resulted in the abandonment of arable lands and in crop farmers clustering together to reduce risks associated with livestock damage. Fencing can be (and is) erected by crop farmers, but represents a cost that has been transferred (externalised) to the crop farmers as a result of a change in the livestock management institutions. In addition, grazing tends to be focussed near the homestead resulting in higher degradation of these areas. Areas further away are under less pressure, which may be a benefit as livestock can be taken to these areas when necessary, such as in times of drought. Another important consequence of livestock remaining closer to the homesteads is that their nutritional intake decreases. This can make livestock more susceptible to disease, increase mortality and reduce calving or kidding rates. The rules regarding maintaining animal health, particularly in relation to dipping and vaccination appear to remain quite strong at both sites, as do the rules for the sale of livestock.

An interesting observation regarding women and livestock, which also extends to other spheres of decision-making within the homestead, is that behind the scenes women do play an important role in decision-making and men will consult with women in the household regarding important decisions.

5 FINDINGS OF WATER PRODUCTIVITY RESEARCH

Low levels of crop productivity remain a challenge for subsistence farmers and this affects their food security status (Backeberg, 2009). Although South Africa may be regarded as food secure at a national level, food insecurity and malnutrition are highest in provinces with large rural populations, such as KwaZulu-Natal, Eastern Cape, Free State and Limpopo (Backeberg, 2009). Subsistence farmers in this sphere are farming under marginal biophysical conditions, experiencing erratic rainfall, high evaporative losses, poor soils and high runoff losses and hence low crop productivity. RWH&C has been reported to increase crop productivity to up to 50%. This is a technique of collecting, channelling and storing water using on-farm methods such as contour ridges and runoff strips (Backeberg, 2009). Research by van Rensburg (2009) suggested that there is a 50% chance that RWH&C will increase smallholder subsistence maize yields from 1.3 to 2.3 $t.ha^{-1}$ when compared to conventional tillage methods.

The other principle of RWH&C is to achieve improved water productivity, which is defined as the amount of agricultural output per unit of water depleted (Descheemaeker et al., 2013). The key to improving water productivity in rainfed cropping systems is to choose well-adapted crop types, reduce unproductive water losses and improve nutrient and agronomic management practices (Descheemaeker et al., 2013). However, these requirements are difficult to achieve in subsistence crop production scenarios. RWH&C can at least contribute to reducing unproductive water losses by collecting runoff water and storing it in the soil profile.

In this study crop water productivity of RWH&C and the current cultivation practice was evaluated through physical methods (measuring yield and soil water content) and the application of a simulation model called AquaCrop. AquaCrop is water-driven, canopy level, engineering (functional) type model that maintains a balance between robustness and output accuracy. It can be used as a generic crop water productivity model and can be applied to a wide range of crops with minimum input parameters (Steduto et al., 2009; Raes et al., 2009).

The first section of this chapter contextualises the drought that occurred at the research sites over the research period. The impact of the drought was substantial at the Muden (KZN) sites, but less so at Ntshiqo (EC). Secondly, the outcomes of the baseline surveys to determine current levels of productivity in selected villages at EC and KZN are provided. The aim of this part of the research was evaluate crop responses to RWH&C with respect to crop yields and water productivity. The final section of the chapter considers livestock production and livestock water productivity, followed by a discussion of the outcomes of the research.

5.1 Productivity in the context of the prevailing drought

Prior to discussing current levels of productivity, it is helpful to first provide a context for the recent drought that has occurred.

In Msinga, for two of the three seasons in question (2014/2015 and 2015/2016), severe drought meant that it was not possible to obtain baseline crop yield information from neighbouring farmers who were not participating in the trial. Most farmers did not plant in the 2014/2015 and 2015/2016 due to late arrival of rains and low initial rainfall. However, with support from the INR, farmers participating in the demonstrations planted for both the years in question with the hope of achieving results from the demonstration to inform the research, which are discussed in .

5.1.1 Ntshiqo, Eastern Cape

Weather data for Ntshiqo for the period July 2013 to June 2015 was obtained from an Automated Weather Station (AWS) at the Tsolo Agricultural Development Institute, approximately 10 km from the Ntshiqo site. However, the AWS became faulty and could not provide weather data from July 2016. As a result the data was patched using the simple arithmetic average of four stations located around the Tsolo area (Moelesti et al., 2016). Locations of these sites are as follows (Table 5.1).

Table 5.1: Rainfal from nearest rainstations surrounding research sites

Comp#	Station Name	Latitude	Longitude	Altitude
30433	MHLANGA - LIBODE	-31.44818	28.94299	1118
30539	UMTATA	-31.58024	28.77543	685
30559	UMTATA: ROSS MISSION	-31.54272	28.61539	800
30610	MACLEAR: SOMERTON	-31.15626	28.38402	1254

A composite of the annual and monthly rainfall figures are provided in Figure 5.1 and Figure 5.2.

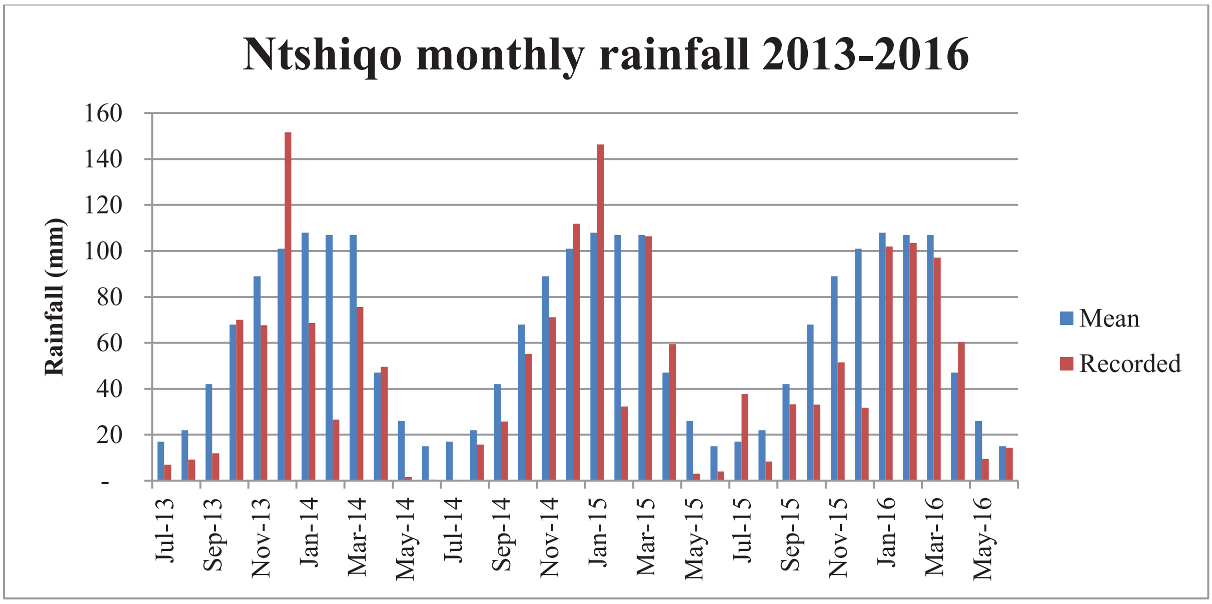


Figure 5.1: Monthly rainfall and long-term mean monthly rainfall from the Tsolo AWS for the period July 2013 to May 2016 (3 growing seasons)

Figure 5.1 shows clear spikes in rainfall in December 2013 and December 2014. However, rainfall was well below average for January to March 2014 and in February 2015, which are critical periods in the growth of maize. Rainfall in the 2015/2016 season was low in the early summer, but good rains were received from January to April 2016. Overall, annual rainfall was below the annual mean for the three years in question (Figure 5.2). However, annual rainfall remained higher than 500 mm, which is usually sufficient for a maize production.

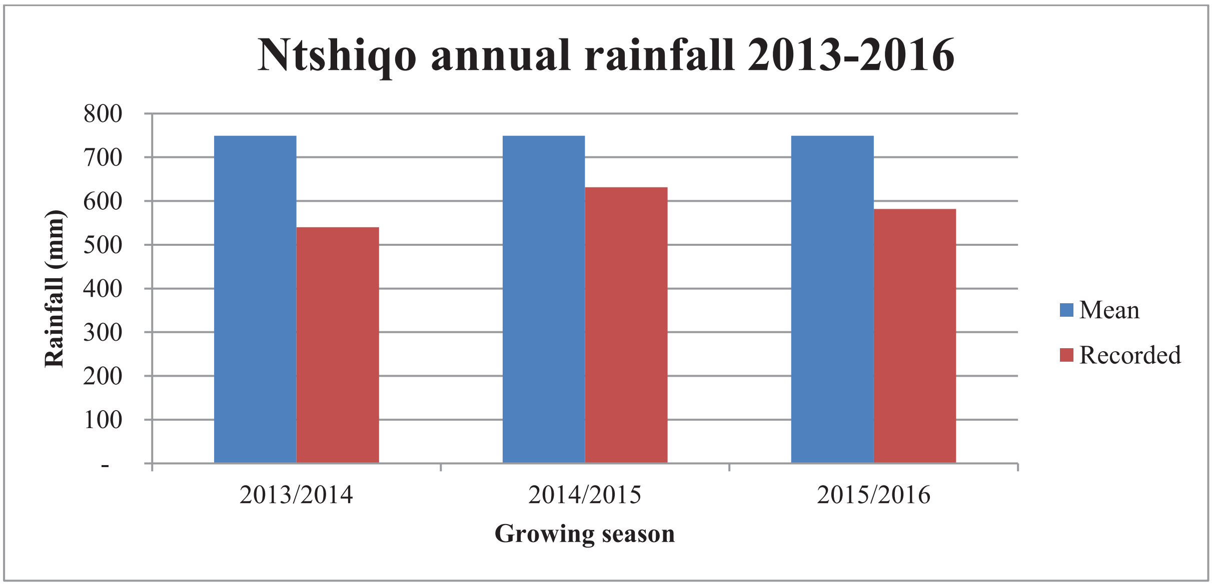


Figure 5.2: Recorded annual rainfall from the Tsolo AWS compared against the mean annual rainfall

5.1.2 Muden, KwaZulu-Natal

In Muden, AWSs were installed at the Fabeni and Mxheleni sites in KwaZulu-Natal in December 2014 and rainfall from January 2015 onwards reflects the recorded rainfall from these weather stations. Rainfall data from July 2013 to December 2014 were obtained from a South African Sugar Research Institute (SASRI) weather station located in Muden town, approximately 20 km from Fabeni and 11 km from Mxheleni, with mean annual rainfall of 680 mm. This was used to approximate the rainfall received at Mxheleni and Fabeni for the period in question. The next closest rain station was located in Greytown, 30 km from the site, but with a mean annual rainfall of over 1000 mm. The difference in mean rainfall meant that this site would not have provided a good proxy for the Muden sites which have annual rainfall of approximately 600 mm. Monthly rainfall data for the Fabeni and Mxheleni research sites are provided in Figure 5.3 and Figure 5.4. Annual rainfall figures for the Fabeni and Mxheleni sites are provided in Figure 5.5.

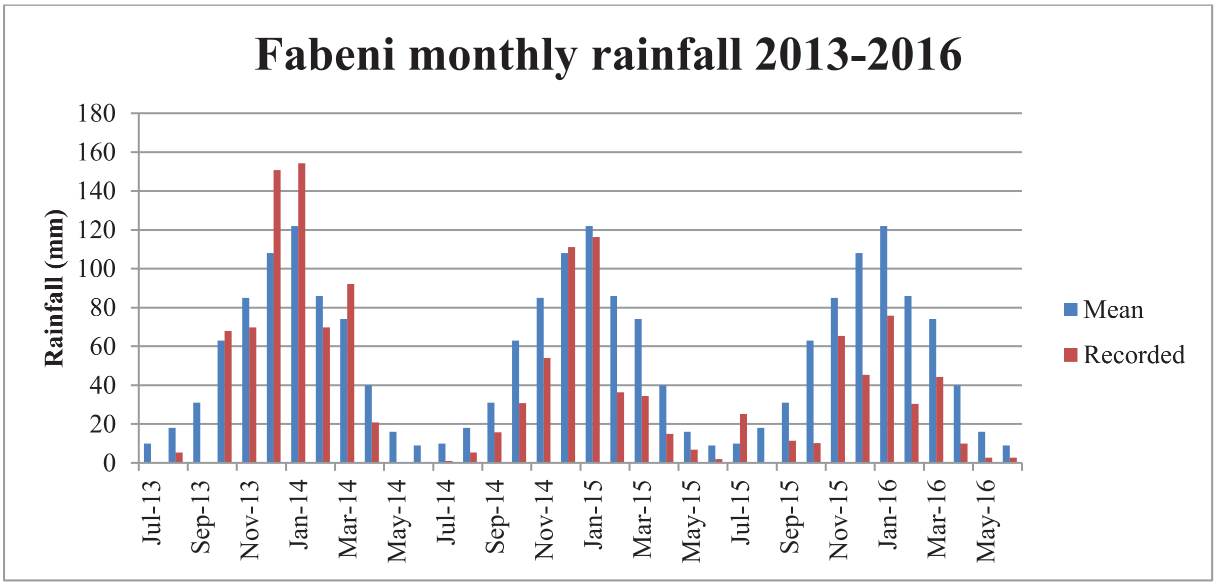


Figure 5.3: Monthly rainfall for the Fabeni research site compared against the long-term means (2013-2016)

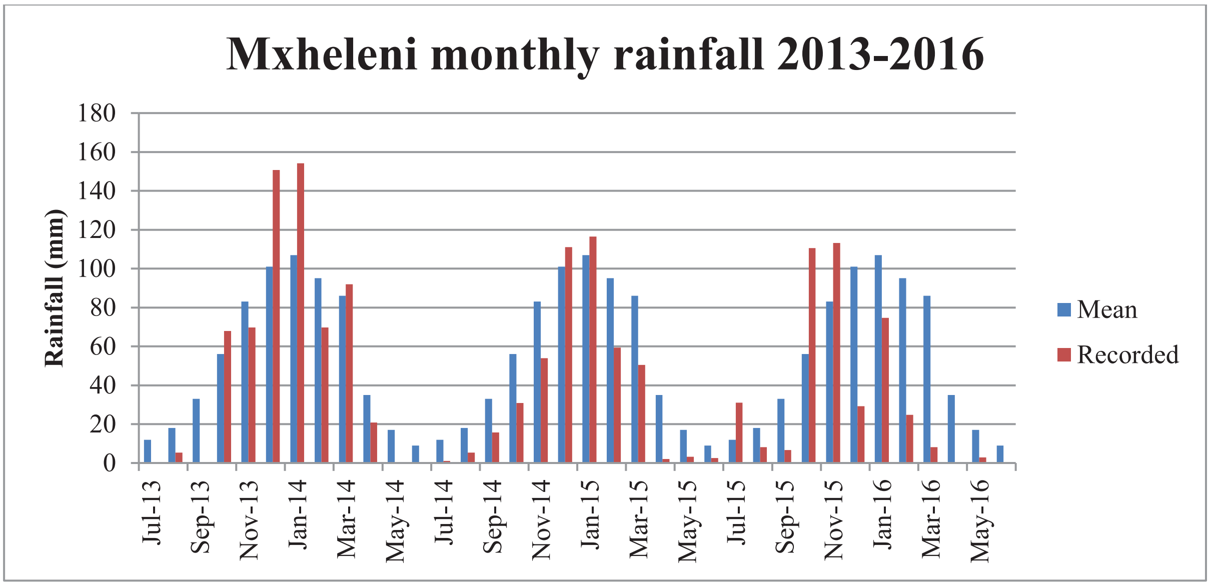


Figure 5.4: Monthly rainfall for the Mxheleni research site compared with the long-term means (2013-2016)

According to the available rainfall data from the Muden weather station, the 2013/2014 production season was a good year from a rainfall perspective, with above average rainfall occurring for the year. Furthermore, the rainfall was well distributed through the growing season, with only a slight dip below the mean in February 2014. It should be noted, however, that local variations in rainfall do occur and this data may not necessarily represent actual rainfall received at the research sites.

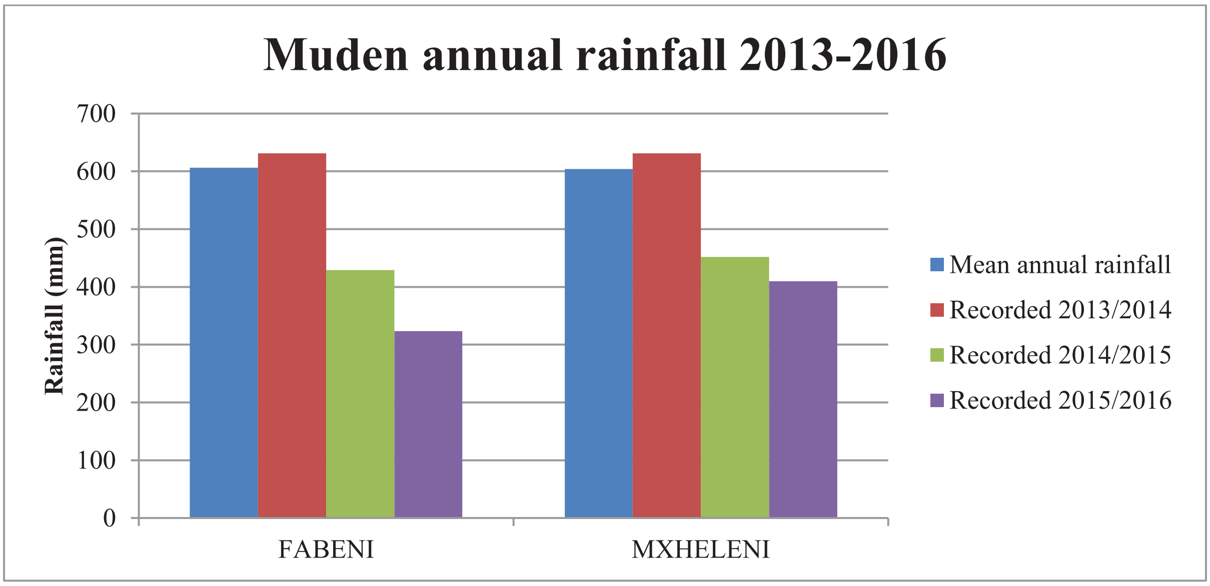


Figure 5.5: Annual rainfall for the Fabeni and Mxheleni research sites at Muden, KwaZulu-Natal (2013-2016)

The 2014/2015 season saw a notable decrease in rainfall, with Fabeni receiving 429 mm for the year. Good rains did occur in December and January, however rainfall in February to March was half that of the mean. Furthermore, in the months prior to planting, rainfall was about half of the average for September to November, meaning that moisture reserves in the soil were low. 2015/2016 saw a further decrease in annual rainfall, with Fabeni receiving only 324 mm rainfall, well below the mean throughout the growing season.

Figure 5.6: Stark reminder of the drought in Muden – both people and livestock are reliant on surface water resources

Mxheleni received 452 mm in the 2014/2015 growing season. Above average rainfall occurred in December and January, however February and March saw a substantial reduction in rainfall. As with Fabeni, rainfall in the months prior to planting was also low. In the 2014/2016 season, Mxheleni received 410 mm for the season. Above average rainfall occurred in October and November, however very poor rainfall occurred in December and February and, to a lesser extent in January.

It is within this context that the challenges of evaluating baseline productivity from both a crop and livestock perspective at Muden needs to be understood. Measurements were initiated in 2014/2015 at the onset of the drought and as a result, very low levels of productivity were recorded, which are unlikely to reflect production in an average year.

5.2 Current levels of productivity and relationships between rain-fed field crop production and livestock production on rangeland

Outcomes of the research are provided below for the Ntshiqo and Muden sites.

5.2.1 Productivity in Ntshiqo, Eastern Cape (Site 1)

This sections details the outcomes of baseline evaluations and surveys of crop and livestock productivity conducted in the 2013/2014 and 2014/2015 seasons.

Baseline cropping survey

Surveys were conducted with eight farmers in Ntshiqo in the 2013/2014 and 2014/2015 growing seasons. The purpose of this was to determine a baseline for yields that farmers are obtaining, rather than relying on recall. Two farmers living nearby to each of the five farmers participating in the trials were selected for the surveys. Farmers were interviewed to record yields of all staple crops grown in their homestead gardens, namely maize, dry beans and squashes. Farmers recorded maize yields by counting the number of green maize cobs harvested and by measuring the number of litres of dry grain harvested. Based on the measurements taken from the RWH&C field trials, a mean grain mass of 0.17 $kg.cob^{-1}$ was calculated, which was used to estimate the dry grain yield from the green maize harvested. Samples of dry grain in 10 litre containers were weighed to determine the volume:mass relationship. This was found to be close enough to 1:1 (readings were 10 kg, 10 kg, 10.2 kg and 10.1 kg) that this conversion rate could be used. Similar results were obtained for dry bean yields. Pumpkin yield was extrapolated based on the number of pumpkins harvested on a total number per hectare basis. Using the area of the homestead gardens, a yield per hectare for the three crops was calculated.

The baseline yields for the 2013/2014 and 2014/2015 cropping seasons are provided in Table 5.2 and discussed below. Eight households neighbouring the demonstration sites provided information on crop yields, with interviews conducted in June 2014 and July 2015.

Table 5.2: Baseline assessment of yields from homestead gardens not participating in the trial (Ntshiqo)

Name of farmer	Dry maize yield ($kg.ha^{-1}$)		Dry bean yield ($kg.ha^{-1}$)		Pumpkin yield ($number.ha^{-1}$)	
	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
Nokhwezi Madolo	1 901.75	2 670.88	-	59.65	-	-
Mkathembile Rangana	1 246.61	1 438.61	43.48	295.65	86.96	278.26
Nowinile Hlabiso	457.52	2 123.89	-	75.22	-	66.37
Nokwanda Mponco	3 686.32	2 000.00	-	44.74	-	126.32
Nogcinikhaya Dube	300.00	583.58	-	-	-	-
Nosibulele Cele	596.77	2 188.71	-	274.19	-	483.87
Nobongile Hlokoza	747.66	1 207.29	-	-	-	-
Nowinjile Hlokoza	624.41	933.10	262.07	117.24	379.31	41.38
Mean	1 195.13	1 643.26				
Median	686.04	1 719.30				

Maize grain yields reported were highly variable, ranging from 300 $kg.ha^{-1}$ to 3 686 $kg.ha^{-1}$ in 2013/2014. There was slightly less variation in yields for the 2014/2015 season (580 $kg.ha^{-1}$ to 2 670 $kg.ha^{-1}$). This is reflected in the higher median value for the 2014/2015 season, compared with 2013/2014. The mean for the 2014/2015 season was 280 $kg.ha^{-1}$ greater than the previous year. However, the accuracy of the information provided by the farmers, particularly regarding their recollection of consumption of green maize, is questionable and is likely to be overestimated in some cases.

In 2013/2014, only two of the farmers surveyed had planted dry beans and pumpkins in their homestead gardens, while in 2014/2015, six of the eight farmers surveyed had planted beans. A similar trend was noted in pumpkin production.

Farmers were also asked to indicate the amount of maize grain used for own consumption, as livestock feed and saved for planting in the next season. The results of this are provided in Figure 5.7 and Figure 5.8.

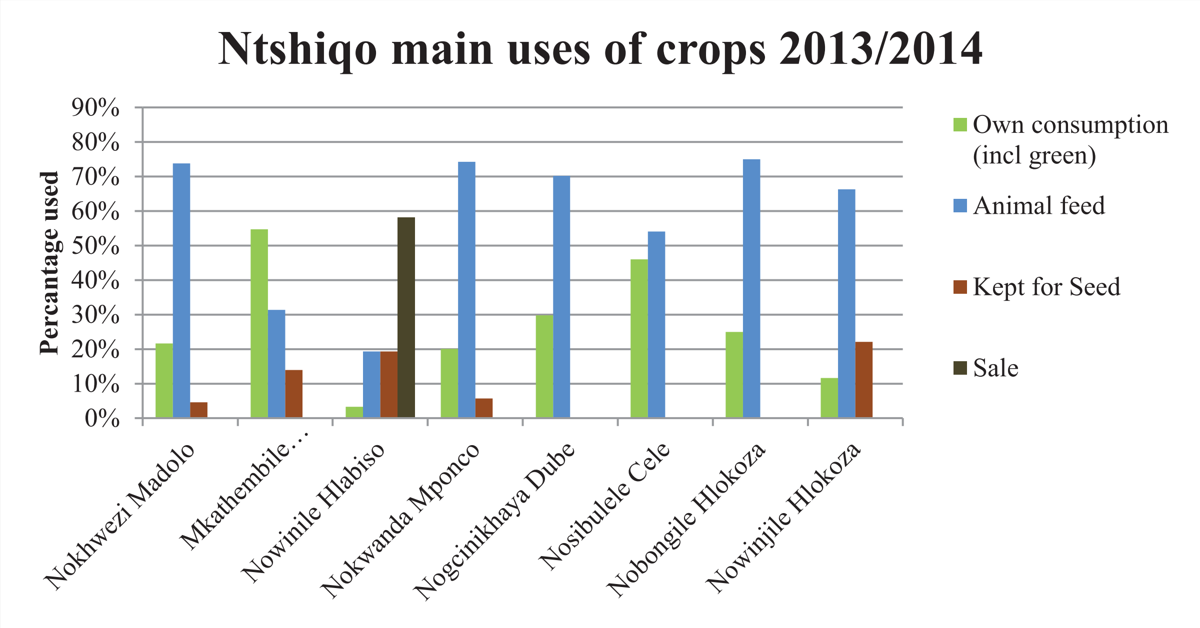


Figure 5.7: Proportion of maize used for own consumption, livestock feed, and saved for seed (Ntshiqo - 2013/2014)

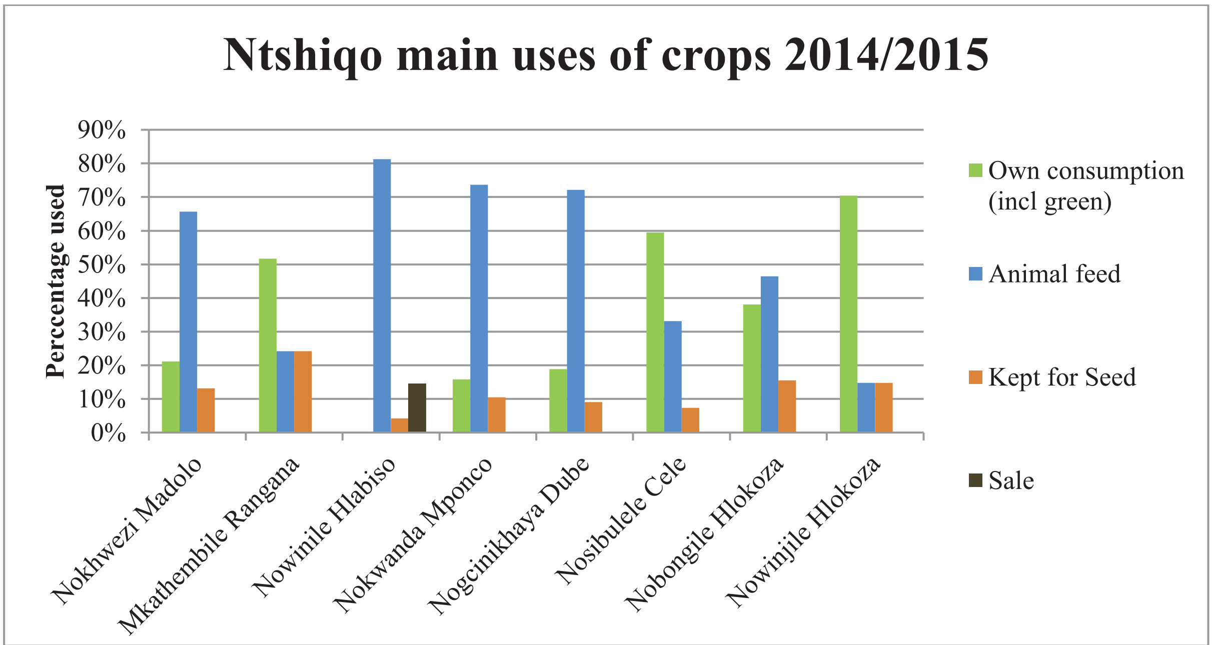


Figure 5.8: Proportion of maize used for own consumption, livestock feed, and saved for seed (Ntshiqo - 2014/2015)

What is notable across both seasons is the high proportion of seed that is used for livestock feed. Respondents indicated that most of the grain used for livestock is given to sheep and chickens. In severe winters, maize is also fed to cattle. The proportion of feed allocated to livestock highlights the value of livestock to people living in Ntshiqo.

Farmers were also asked how their harvest contributes to household requirements, how they obtain the additional food they need and whether or not they employ labour in their homestead gardens. The results are provided in Table 5.3, Table 5.4 and Table 5.4 and discussed below.

Table 5.3 Contribution of homestead garden yield to household requirements at Ntshiqo, Eastern Cape

Farmer	Contribution of maize to household requirements
Nokhwezi Madolo	Mostly contributes to livestock feed because most of the harvested maize is used to feed livestock.
Mkathembile Rangana	It contributes a little because I only use maize as umnqushu (samp); the rest is for animal feed.
Nowinile Hlabiso	It does not contribute much to food needs because I use all the maize to feed livestock. It is important for livestock.
Nokwanda Mponco	It contributes a lot because I don't have to buy feed for my pigs and chickens. I don't buy maize meal because I mill the harvested maize.
Nogcinikhaya Dube	This year the harvest was not good because of drought, so the harvest didn't contribute much to my needs
Nosibulele Cele	Contributes about 80% to the family needs because I don't buy maize meal, samp and beans. In summer I grow vegetables and only buy meat and cooking oil.
Nobongile Hlokoza	This year the yield was not good but I would say usually the harvest from the garden contributes 50% of my family needs because I harvest for both feeding livestock and home consumption.
Nowinjile Hlokoza	I mill the maize hence I don't buy maize meal and I also don't buy beans meaning less money for groceries.

The responses further indicate that a large proportion of the yield from homestead gardens is used for feeding livestock. This also suggests that farmers do not rely heavily on homestead gardens directly for food security (rather to feed livestock – an indirect form of food security) and that cash is used to purchase household food needs. In light of this, respondents were asked how they get the additional food they need to meet household food needs.

Table 5.4 Source of additional food needed for the homestead / family needs in Ntshiqo, Eastern Cape

Farmer	Means of obtaining food
Nokhwezi Madolo	Old age grant
Mkathembile Rangana	Social grant, in good years I grow and sell vegetables but this year there was frost so vegetables didn't do well
Nowinile Hlabiso	Social grant plus selling chicken and pigs
Nokwanda Mponco	Social grants (old age + child support)
Nogcinikhaya Dube	Grant
Nosibulele Cele	Social grant and selling chicken and pigs. Head of the house works part-time if something comes up.
Nobongile Hlokoza	Social grant and I also sell grain from "insimu" (fields)
Nowinjile Hlokoza	Social grant

It should be noted that respondents were reluctant to divulge their sources of income for buying food and the interviewer got the sense that some respondents did not reveal all their income sources. Nevertheless, all respondents indicated that social grants were the main source of income for securing additional food for the homestead. This highlights the importance of social grants in meeting food security requirements. It is also important to note that most homestead farmers are retired, so social grants are more likely to be an important source of income and younger household members may be working elsewhere and earning income.

Table 5.5 Use of labour by surveyed households in Ntshiqo, Eastern Cape

Farmer	Households make use of paid labour
Nokhwezi Madolo	No.
Mkathembile Rangana	2 people, pay them after harvest approximately R300.
Nowinile Hlabiso	5 people, pay them R60 per 5 hours, I sell pigs because they have a good value and use this money to pay labour.
Nokwanda Mponco	No.
Nogcinikhaya Dube	No.
Nosibulele Cele	No.
Nobongile Hlokoza	1 person, R50 per day.
Nowinjile Hlokoza	No, but I see the need now because I am getting old.

Three of the eight respondents indicated that they hire labour to assist in the homestead garden, paying between R50 and R60 per day. A day's work is usually from 06:00 to 11:00, which translates to an hourly rate of R10 to R12 per hour.

Livestock productivity

Livestock play an important role in in the Ntshiqo community from a social, cultural and economic perspective. This section discusses baseline livestock productivity from monthly surveys conducted from 2014 to 2016. The initial survey to understand current levels of livestock productivity, which relied on farmers' recollection of their livestock's performance for the 12 months prior to the interviews conducted in 2013 revealed that more detailed surveys of livestock were necessary. Consequently, herd/flock changes were tracked for 16 selected households from April 2014 to May 2016. The purpose of this was to understand current levels of productivity (e.g. calving/kidding rates, weaning rates, mortality rates, etc.) and offtake through sales, slaughter and other cultural uses of cattle, sheep and goats. Where inputs were used for livestock (e.g. supplements and medicine), these were also recorded. The results of the survey provide an indication of the livestock performance. The livestock surveys in Ntshiqo focussed largely on sheep, as they are the most numerous livestock held by Ntshiqo farmers and to a lesser extent on cattle as these are lower in number, but remain culturally important.

Sheep productivity

Table 5.6 and Table 5.7 provide a summary of information for the flocks of sixteen sheep farmers with respect to the number of ewes owned, lambs born and lambs weaned and hence lambing and weaning percentages, where:

- Lambing percentage = Number of lambs born relative to number of ewes exposed to ram per year
- Weaning percentage = Number of lambs weaned relative to number of ewes exposed per year.

The collective flock structure of the 16 farmers was a total of 864 sheep, composed of 287 ewes, 143 maiden ewes, 71 wethers (castrates) and 20 rams at the end of June 2015. From May 2014 to June 2015, this flock produced a total of 283 lambs in the 12 month period and 219 were weaned (Table 5.6). This gives lambing and weaning percentages of 98% and 76% respectively. The mortality rate for lambs was 23%, representing a loss of R32 000 at a value of R500 per lamb.

Between June 2015 and June 2016, the flock increased to 1001 sheep. With 354 ewes producing 280 lambs, of which 251 were weaned. This gives a lambing and weaning percentage of 79% and 71% respectively, somewhat lower than the previous season. The mortality rate for this season was lower at 10%, representing a loss of R14 500 at a value of R500 per lamb.

It is interesting to note from Table 5.6 and Table 5.7 that eight of the sixteen farmers reported a weaning percentage equal to their lambing percentage (i.e. no mortalities recorded) which is unusual especially with smallholder farmers. The remaining farmers showed some level of losses, thus weaning percentage was less than the lambing percentage, which is to be expected.

Table 5.6: A summary of sheep productivity at Ntshiqo as at June 2015 (for a 12 month period)

Farmer Number		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Summary / Total**
Ewes		4	30	14	5	16	48	21	43	7	1	4	10	5	6	21	52	287
Heifers (Ewe lamb)		0	0	11	9	12	45	0	34	16	0	6	2	1	2	5	0	143
Rams		0	0	1	1	0	8	0	3	0	0	1	2	0	0	2	2	20
Wether / hamel (castrated ram)		0	0	0	0	4	36	4	11	0	0	0	3	0	0	0	13	71
Weaned female lambs (ie ewe lambs)		3	0	4	3	10	42	10	25	8	0	0	14	4	3	20	37	183
Weaned rams		0	0	8	2	16	8	11	31	4	0	0	2	0	0	12	24	118
Female lambs (not weaned)		1	0	4	0	3	0	0	9	5	1	2	8	0	1	0	0	34
Male lambs (not weaned)		0	0	0	0	0	0	0	0	2	0	2	2	0	0	2	0	8
Total lambs born		**1**	**31**	**12**	**5**	**23**	**53**	**21**	**22**	**12**	**2**	**4**	**11**	**5**	**3**	**28**	**50**	283
Total lambs weaned		**1**	**27**	**12**	**5**	**16**	**26**	**21**	**22**	**12**	**1**	**0**	**10**	**5**	**3**	**18**	**40**	**219**
Total Animals		**8**	**30**	**42**	**20**	**61**	**187**	**46**	**156**	**42**	**2**	**15**	**43**	**10**	**12**	**62**	**128**	864
Lambing %		25%	103%	86%	100%	144%	110%	100%	51%	171%	200%	100%	110%	100%	50%	133%	96%	99%
Weaning %		25%	90%	86%	100%	100%	54%	100%	51%	171%	100%	0%	100%	100%	50%	86%	77%	76%
Animals lost (i.e. mortalities)			4			7	27				1	4	1			10	10	64
Value of lambs dying (Rands) @R500/lamb	500		2000			3500	13500				500	2000	500			5000	5000	32 000
Mortality rate (# lambs dying/% of lambs born)			13			30	51				50	100	9			36	20	23%
Expenditure(anthelmintics)			1018	1940	52	1913	4199	1215	2290	1308	29		4380	234		2135	1340	22 053.00
Exp per animal (anthelmintics)			33.93	46.19	2.60	31.36	22.45	26.41	14.68	31.14	14.50		101.86	23.40		34.44	10.47	
Expenditure Antibiotic		20		120	119		800	200	241						150		1150	2 800.00
Exp/animal (Antibiotics)		2.50		2.86	5.95		4.28	4.35	1.54						12.50		8.98	
Expenditure Feed				600			600		2190	180			2130			820	1840	8 360.00
Exp per animal (feed)				14.29			3.21		14.04	4.29			49.53			13.23	14.38	
Other				280				400	800			275				70	290	2 115.00
Exp per animal (other)				6.67				8.70	5.13			18.33				1.13	2.27	
Total Expenditure		20	1018	2940	171	1913	5599	1815	5521	1488	29	275	6510	234	150	3025	4620	35 328.00
Expenditure per animal		**2.5**	**33.9**	**70.0**	**8.6**	**31.4**	**29.9**	**39.5**	**35.4**	**35.4**	**14.5**	**18.3**	**151.4**	**23.4**	**12.5**	**48.8**	**36.1**	**591.57**
Value of lambs weaned (@ R500/lamb)	500	**500**	**13 500**	**6 000**	**2 500**	**8 000**	**13 000**	**10 500**	**11 000**	**6 000**	**500**	**-**	**5 000**	**2 500**	**1 500**	**9 000**	**20 000**	**109 500.00**

Table 5.7: A summary of sheep productivity at Ntshiqo as at June 2016 (for a 12 month period)

Farmer Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Summary / Total
Ewes		7	37	23	5	21	65	20	44	13	1	4	32	4	2	22	54	354
Heifers (Ewe lamb)		0	0	0	6	10	58	11	7	17	0	2	0	0	4	25	12	152
Rams		0	0	1	1	0	2	2	3	4	0	0	2	0	0	1	2	18
Wether / hamel (castrated ram)		0	4	3	0	13	11	23	13	0	0	0	22	0	0	21	25	135
Weaned female lambs (ie ewe lambs)		3	18	8	1	7	22	12	19	7	0	1	22	0	0	6	23	149
Weaned rams		0	13	17	1	4	20	2	19	5	0	1	4	1	0	8	23	118
Femle lambs (not weaned)		0	0	0	0	0	0	0	19	0	0	0	19	2	0	0	0	40
Male lambs (not weaned)		0	0	0	0	0	0	0	18	0	1	0	14	2	0	0	0	35
Total lambs born		4	31	18	2	11	57	17	37	7	1	3	23	4	0	17	48	280
Total lambs weaned		**3**	**31**	**18**	**2**	**11**	**42**	**14**	**37**	**7**	**0**	**2**	**23**	**1**	**0**	**14**	**46**	251
Total Animals		**10**	**72**	**52**	**14**	**55**	**178**	**70**	**142**	**46**	**2**	**8**	**115**	**9**	**6**	**83**	**139**	1001
Lambing %		57%	84%	78%	40%	52%	88%	85%	84%	54%	100%	75%	72%	100%	0%	77%	89%	79%
Weaning %		43%	84%	78%	40%	52%	65%	70%	84%	54%	0%	50%	72%	25%	0%	64%	85%	71%
Animals lost (i.e. mortalities)		1	0	0	0	0	15	3	0	0	1	1	0	3	0	3	2	29
Value of lambs dying (Rands) @R500/lamb	500	500	0	0	0	0	7500	1500	0	0	500	500	0	1500	0	1500	1000	14500
Mortality rate (# kids dying/% of kids born)		25%	0%	0%	0%	0%	26%	18%	0%	0%	100%	33%	0%	75%	0%	18%	4%	10%
Expenditure Int Parasite		90	310	295	52	130	4 680	213	198	189				39	180	392	475	7 243
Exp per animal (anthelmintics)		9	4	6	4	2	26	3	1	4				4	30	5	3	102
Expenditure Antibiotic			200		240	187	600		1 260	398		79	712	39	110	469	480	4 774
Exp/animal (Antibiotics)			3		17	3	3		9	9		10	6	4	18			83
Expenditure Feed						110	400		610				280			340	740	2 480
Exp per animal (feed)						2	2		4				2			4	5	20
Other																		-
Exp per animal (other)																		
Total Expenditure		90	510	295	292	427	5 680	213	2 068	587	-	79	992	78	290	1 201	1 695	14 497
Expenditure per animal		**9.00**	**7.08**	**5.67**	**20.86**	**7.76**	**31.91**	**3.04**	**14.56**	**12.76**	**0.00**	**9.87**	**8.63**	**8.67**	**48.33**	**14.47**	**12.19**	**214.82**
Value of lambs weaned (@ R500/lamb)	500	**1 500**	**15 500**	**9 000**	**1 000**	**5 500**	**21 000**	**7 000**	**18 500**	**3 500**	**-**	**1 000**	**11 500**	**500**	**-**	**7 000**	**23 000**	**125 500**

Table 5.8 illustrates the expenditure with respect to medication and feed per farmer for sheep, and the overall expenditure on inputs per animal (for the 16 farmers). To simplify the presentation of the data on expenditure on inputs, a summary table has been drawn to explain the general trends on expenditure.

The total expenditure of all the inputs in the collective flock for the 12 months ending in March 2015 was R35 238 and the value of lambs weaned was R109 500, which translates to a profit of R74 262 (assuming no labour cost). The total expenditure per flock per year ranged from R20 to R6 510. Between June 2015 and June 2016, expenditure on inputs was R14 500 and the value of lambs weaned was R125 500, giving a profit of R111 000.

While for most farmers (87.5%), the value of the lambs weaned far exceeded the cost of inputs, this was not the case for one farmer with a flock of 43 sheep who spent R6 510 on inputs while the value of lambs weaned in that period was only R5 000. The risk of investing in inputs is demonstrated by another farmer, who only spent R275 on inputs (specifically a vitamin supplement) and lost all 4 lambs that were born.

Table 5.8: Expenditure on inputs across 16 selected sheep farmers at Ntshiqo, Eastern Cape

Input	**No. of farmers purchasing inputs**	**Percentage of farmers**	**Price range (R/animal)**		**Mean expenditure per animal (R)**
			Low	High	
April 2014 to March 2015					
Anthelmintics	13	81%	2.60	101.86	25.52
Antibiotics	8	50%	1.54	12.50	3.24
Feed (Master 20)	7	44%	3.21	49.53	9.68
Other	6	38%	1.13	18.33	2.45
April 2015 to June 2016					
Anthelmintics	13	81%	1.39	30.00	7.24
Antibiotics	12	75%	2.78	18.33	4.77
Feed	6	38%	2.00	5.32	2.48
Other	0	0%	-	-	0

Table 5.8 indicates that the greatest expenditure across both years was for anthelmintics, which are used to control internal parasites. Expenditure reported by farmers in 2014/2015 was higher (total of R35 328, of which R22 000 was anthelmintics) compared with 2015/2016 (total R14 400 of which R7 400 was anthelmintics).

The data also show that the farmers who own a high number of sheep are willing to spend more money on inputs. Farmers with flock sizes between 30 and 156 sheep, spent between R1000 and R5600 annually on inputs. This pattern can be related to the family wealth; generally households with more livestock are considered to be wealthier than those with few livestock.

Cattle productivity

Table 5.10 and Table 5.11 provide a summary of the productivity of cattle in Ntshiqo for the survey period. Eight of the sixteen farmers surveyed kept cattle. There were a total of 44 animals in the first survey year. This was made up of 16 cows, 9 heifers, 1 bull, 11 oxen, 3 weaners and 12 calves. Of the 12 calves born during this period, 11 were weaned, giving a calving percentage of 75% and a weaning percentage of 69%.

In the second survey year, there were a total of 31 cattle, made up of 14 cows, 5 heifers, 2 oxen and 4 weaners. Six calves were born during this period, although only two survived to weaning. One farmer lost four calves, resulting in an overall calving percentage of 43% and a weaning percentage of only 14%. Two farmers moved their cattle to a private farm in Maclear, resulting in the drop in total livestock numbers.

Table 5.9 illustrates the expenditure with respect to medication and feed per farmer and the overall inputs per animal. Only eight of the sixteen farmers surveyed owned livestock.

The total expenditure of all the inputs in the collective herd for the 12 months ending in March 2015 was R3 560 and the value of calves weaned was R4 000, which translates to a profit of R440 (assuming no labour cost). The total expenditure per herd per year ranged from R0 to R1 742. Between June 2015 and June 2016, total expenditure on inputs was R593 and the value of calves weaned was R2 000 giving a profit of R1 407. The total expenditure per herd per year ranged from R0 to R365.

Table 5.9: Expenditure on inputs across 8 cattle farmers at Ntshiqo, Eastern Cape

Input	**No of farmers purchasing inputs**	**Percentage of farmers**	**Price range (R/animal)**		**Mean expenditure per animal**
			Low	High	
April 2014 to March 2015					
Anthlemintics	4.00	50%	21.00	199.43	47.93
Antibiotics	-	0%	-	-	-
Feed	2.00	25%	4.20	15.71	3.45
Other	2.00	25%	40.00	44.44	18.18
April 2015 to June 2016					
Anthlemintics	-	0%	-	-	-
Antibiotics	3.00	38%	4.67	40.56	16.23
Feed	-	0%	-	-	-
Other	3.00	38%	4.67	40.56	19.13

Table 5.10: Livestock productivity – cattle in Ntshiqo (April 2014 to June 2015)

Farmer	1	2	3	4	5	6	7	8	Summary/ Total
Cows	2	2	0	2	4	1	3	2	16
Heifers	0	2	0	2	1	2	1	1	9
Bulls	1	0	0	0	0	0	0	0	1
Oxen	2	3	2	1	1	2	0	0	11
Weaned cows (heifers)	0	0	0	2	0	1	0	0	3
Weaned bulls	0	0	0	0	0	0	0	0	0
Female calves	0	1	0	2	2	1	0	0	6
Male calves	1	2	0	0	2	0	0	1	6
Total number of animals	**6**	**10**	**2**	**9**	**10**	**7**	**0**	**0**	**44**
Total calves born	2	3	0	2	4	1	0	0	12
Total calves weaned	1	3	0	2	4	1	0	0	11
Total Calving %	100%	75%	0%	100%	100%	100%	0%	0%	75.0%
Total Weaning %	50%	75%	0%	100%	100%	100%	0%	0%	69%
Animals lost (i.e. mortalities)	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1
Value of weaned calves dying (Rands) @R2000/calf	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4 000
Mortality rate (# calves dying/% of calves born)	50%	0	0	0	0	0	0	0	8%
Expenditure Int Parasite	-	210.00	398.85	-	1 100.00	400.00	-	-	2 108.85
Exp per animal (anthelmintics)		21.00	199.43	-	110.00	57.14	-	-	47.93
Expenditure Antibiotic	-	-	-	-	42.00	110.00	-	-	152.00
Exp/animal (Antibiotics)		-	-	-	4.20	15.71	-	-	3.45
Expenditure Feed	120.00	-	-	-	200.00	80.00	-	-	400.00
Exp per animal (feed)	20.00	-	-	-	20.00	11.43	-	-	51.43
Other	100.00	-	-	400.00	400.00	-	-	-	800.00
Total Expenditure	220.00	210.00	398.85	400.00	1 742.00	590.00	-	-	3 560.85
Expenditure per animal	36.67	21.00	199.43	44.44	174.20	84.29	-	-	560.02

Table 5.11: Livestock productivity – cattle in Ntshiqo (June 2015 to June 2016)

Farmer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Summary/ Total**
Cows	2			2	4	1	3	2	14
Heifers	0			1	1	2	0	1	5
Bulls	0	Cattle	Cattle	0	0	0	0	0	0
Oxen	0	Moved	Moved	1	0	1	0	0	2
Weaned cows (heifers)	1	to	to	2	0	1	0	0	4
Weaned bulls	0	Maclear	Maclear	0	0	0	0	0	0
Female calves	0			0	2	1	0	0	3
Male calves	0			0	2	0	0	1	3
Total number of animals	**3**			**6**	**9**	**6**	**3**	**4**	**31**
Total calves born	0	0	0	0	4	1	0	1	6
Total calves weaned	0			0	0	1	0	1	2
Total Calving %	50%			100%	100%	100%	0%	50%	43%
Total Weaning %	50%			50%	0%	100%	0%	50%	14%
Animals lost (i.e. mortalities)	0			0	4	0	0	0	4
Value of weaned calves dying (Rands) @R2000/calf	0			0	2000	0	0	0	2000
Mortality rate (# calves dying/% of calves born)	0			0	100	0	0	0	100
Expenditure Int Parasite	90								90.00
Exp per animal (anthelmintics)	30.00			-	-	-	-	-	30.00
Expenditure Antibiotic				28.00	365.00	110.00			503.00
Exp/animal (Antibiotics)				4.67	40.56	18.33	-	-	16.23
Expenditure Feed									-
Exp per animal (feed)									-
Other									-
Total Expenditure	90.00	-	-	28.00	365.00	110.00	-	-	593.00
Expenditure per animal	30.00	-	-	4.67	40.56	18.33	-		93.56

Discussion of livestock productivity

The lambing percentage as at June 2015 ranged between 25% (a flock comprising 4 ewes) and 200% (a flock with 1 ewe), while the average figures for all 16 flocks for lambing was 99%. The weaning percentage was found to range from 0% to 100% with an average of 76%.

For the period ending in June 2016, lambing percentage ranged from 0% to 100%, with an average of 79%. The weaning percentage ranged from 0% to 85%, with an average of 71%.

This highlights that farmers are not obtaining even a single weaned lamb from each adult ewe in a 12 month period. These can be compared with figures from commercial herds which are in the region of 160% (up to 190%) for lambing percentage and 132% (up to 171%) for weaning percentage (OMAFRA, 2015)[3].

To better understand if productivity was higher among farmers who had large flocks (i.e. more commercial farmers), their figures were isolated to determine if productivity was higher. The four farmers with the highest number of ewes were selected and the results are compiled in Table 5.12. Observation across these four farmers showed that the lambing percentage ranged from 51% to 110% and their weaning % ranged from 51% to 90% for 2014/2015, while lambing and weaning percentages were more consistent in 2014/2015, ranging from 84% to 88% and 65% to 85% respectively. This is not substantially different from the combined flock of the 16 farmers.

Table 5.12: Flocks with relatively high ewe numbers and their respective lambing and weaning percentages, Ntshiqo, Eastern Cape

2014/2015				2015/2016			
No of ewes	**Lambing %**	**Weaning %**	**Expenditure per animal**	**No of ewes**	**Lambing %**	**Weaning %**	**Expenditure per animal**
30	103%	90%	R33.9	37	84%	84%	7.08
48	110%	54%	R29.9	65	88%	65%	31.91
43	51%	51%	R35.4	44	84%	84%	14.56
52	96%	77%	R36.1	54	89%	85%	12.19
Mean	**111%**	**66%**		**Mean**	**87%**	**78%**	

Compared with sheep, farmers' expenditure on cattle was much lower, suggesting that sheep are considered to be more important than cattle. Estimated profit, determined by the value of calves weaned against expenditure on inputs was R440 and R1 407 for 2014/2015 and 2015/2016 respectively, compared with R74 262 and R111 000 for sheep during the same period. This suggests that from a financial perspective, sheep are considerably more important than cattle for farmers in Ntshiqo. Furthermore, only eight of the sixteen farmers surveyed owned cattle. Weaning percentages for cattle were 69% and 14% for 2014/2015 and 2015/2016

[3] http://www.omafra.gov.on.ca/english/livestock/sheep/facts/benchmrk.htm

respectively. Weaning rate in 2014/2015 was comparable to that of a commercial herd in South Africa, but was substantially lower in 2015/2016 (see Table 2.4).

5.2.2 Productivity in Muden, KwaZulu-Natal (Site 2)

Baseline cropping survey

In Muden, surveys were conducted with eight farmers to determine baseline yields. Four farmers residing adjacent to each of the two research sites (Fabeni and Mxheleni) were selected and yields were recorded.

As indicated in 5.1.2, poor rainfall during the trial period at Muden was problematic. As a result, some of the farmers participating in the survey did not plant at all, while others did plant but experienced crop failure. The yields of the farmers who did achieve some yield are provided in Table 5.13.

Table 5.13: Baseline assessment of yields from homestead gardens not participating in the trial at Muden, KwaZulu-Natal

	2013/2014			
Name of farmer	Area of garden (ha)	Dry grain maize yield ($kg.ha^{-1}$)	Pumpkin yield ($number.ha^{-1}$)	Bean yield ($kg.ha^{-1}$)
Tholwephi Mzolo	0.12	-	-	69.72
Hluphangani Madlala	0.13	-	-	33.03
Khombani Mzila	0.14	207.31	141.75	60.24
Leonard Majola	0.51	-	-	-
Mavis Ngqulunga	0.11	-	-	-
Fengazi Msimang	0.09	-	-	-
Mukeliwe Mchunu	0.52	596.46	-	-
Sethile Dladla	0.29	788.25	34.07	14.48

Grain yields of maize for the 2013/2014 growing season ranged from 207 to 596 $kg.ha^{-1}$, substantially lower than yields achieved in Ntshiqo (Table 5.2). No yields were recorded for the 2014/2015 season due to the drought resulting in widespread crop failure in that season. Of the three farmers who did achieve yields of maize, by far the largest proportion of maize (>80%) was for own consumption. All three farmers kept seed for planting in the next season (5-15% of crop). Two farmers used the grain for animals – this was mainly for feeding poultry.

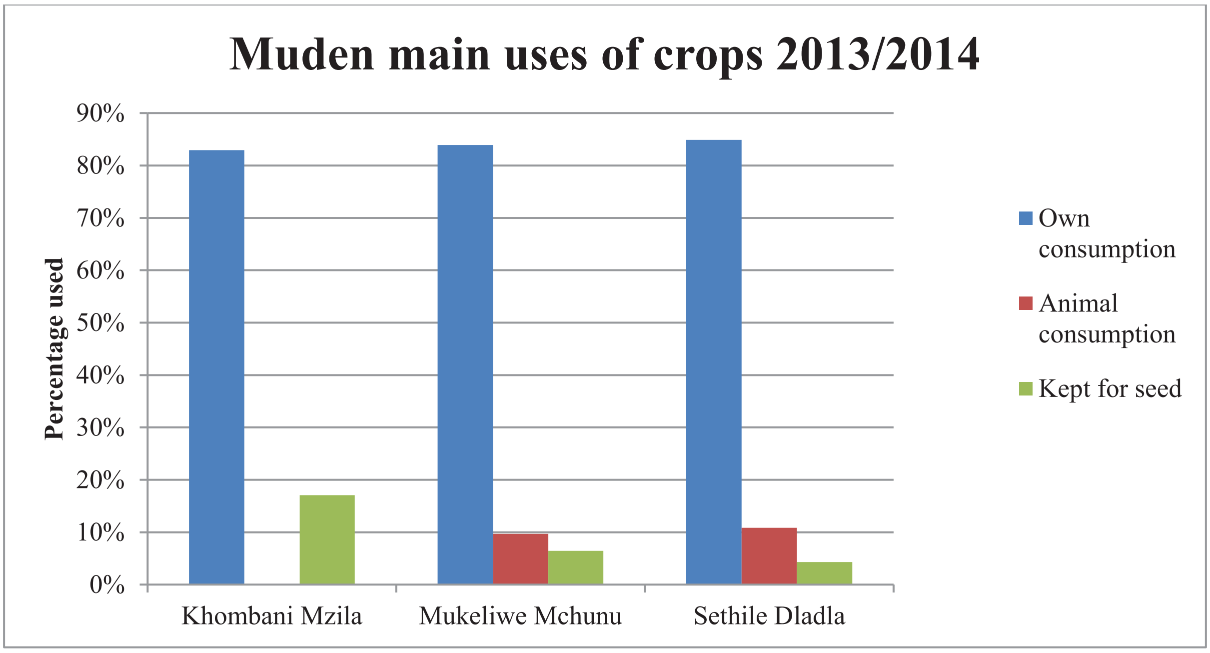


Figure 5.9: Proportion of maize used (by three farmers who obtained yields) for own consumption, livestock feed, and saved for seed (Muden - 2013/2014)

This is in contrast with the grain use for Ntshiqo, where anything from 30-80% of the grain yield is used for livestock, in particular for feeding sheep.

Livestock survey to determine baseline livestock productivity

The initial survey to understand current levels of livestock productivity, which relied on farmers recollection of their livestock's performance for the 12 months prior to the interviews conducted in August 2013, revealed that more detailed surveys of livestock were necessary. Consequently, herd/flock changes were tracked for selected households (n=15) from June 2014 to April 2016. The results of the survey provide an indication of the livestock performance.

Cattle productivity

Table 5.14 provides a summary of the productivity of cattle for the survey period. In the first survey year, there were a total of 147 cattle, belonging to 12 of the 15 farmers participating in the survey. This was made up of 57 cows, 5 heifers, 19 bulls, 11 oxen, 39 weaners and 16 calves. Forty calves were born during this period, of which 21 were weaned, giving a calving and weaning percentage of 70% and 37% respectively.

Table 5.14: Livestock productivity – cattle in Muden (June 2014 to April 2016)

June-2014-April-2015													
Farmer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Summary / Total**
Cows	10	5	3	11	9	1	1	7	4	2	3	1	57
Heifers	0	2	0	0	1	0	0	0	1	0	1	0	5
Bulls	2	0	0	8	4	0	0	2	1	1	0	1	19
Oxen	2	0	0	2	1	0	4	2	0	0	0	0	11
Weaned cows (heifers)	0	1	0	4	5	1	0	4	2	1	0	3	21
Weaned bulls	0	2	0	4	4	1	1	2	1	1	1	1	18
Female calves not weaned	0	1	2	5	0	0	0	1	0	0	1	0	10
Male calves not weaned	0	0	0	4	1	0	0	0	0	0	1	0	6
Total animals	14	11	5	38	25	3	6	18	9	5	7	6	147
Female calves born	6	1	2	4	6	0	0	4	2	1	1	0	27
Male calves born	1	1	0	4	3	0	0	1	1	1	1	0	13
Total calves born	7	2	2	8	9	0	0	5	3	2	2	0	40
Female calves weaned	0	1	0	0	5	0	0	4	2	1	1	0	14
Male calves wened	1	1	0	0	3	0	0	1	1	1	1	0	9
Total Calves weaned	1	2	0	0	8	0	0	5	3	2	0	0	21
Calving percentage	70.00%	40.00%	66.67%	72.32%	100.00%	0.00%	0.00%	71.43%	75.00%	100.00%	66.67%	0%	70%
Weaning percentage	10%	40%	0%	0%	89%	0%	0%	71%	75%	100%	0%	0%	37%
Animals lost (i.e. mortalities)	6	0	2	8	1	0	0	0	0	0	2	0	19
Value of weaned calves dying (Rands) @R2000/calf	12000	0	4000	16000	2000	0	0	0	0	0	4000	0	38000
Mortality rate (# calfs dying/% of calfs born)	85.71	0.00	100.00	100.00	11.11	0.00	0.00	0.00	0.00	0.00	100.00	0.00	53%
April 2015-April-2016													
Cows		0	0	0	0	0	0	0	0	0	3	0	3
Heifers		0	0	0	0	0	0	0	0	0	0	0	0
Bulls		0	0	1	0	0	0	2	0	0	1	0	4
Oxen		1	0	0	0	0	0	0	0	0	0	0	1
Weaned cows (heifers)		1	0	1	1	0	0	0	0	1	1	0	5
Weaned bulls		0	0	0	0	0	1	0	0	1	2	0	4
Female calves not weaned		0	0	0	0	0	0	0	0	0	0	0	0
Male calves not weaned		0	0	0	0	0	0	0	0	0	0	0	0
Total animals		2	0	2	1	0	1	2	0	2	7	0	17
Female calves born		1	1	0	0	0	0	1	0	0	1	0	4
Male calves born		0	0	1	1	0	0	1	0	0	1	0	4
Total calves born		1	1	1	1	0	0	2	0	0	2	0	8
Female calves weaned		0	0	0	0	0	0	0	0	0	0	0	0
Male calves wened		0	0	0	0	0	0	0	0	0	0	0	0
Total Calves weaned		0	0	0	0	0	0	0	0	0	0	0	0
Calving percentage		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	66.67%	0.00%	267%
Weaning percentage		0.00%	0.00%	0.00%	0.00%	0%	0.00%	0.00%	0.00%	0.00%	66.67%	0.00%	0%
Animals lost (i.e. mortalities)		1	1	1	1	0	0	2	0	0	2	0	8
Value of weaned calves dying (Rands) @R2000/calf		2000.00	2000.00	2000.00	2000.00	0.00	0.00	4000.00	0.00	0.00	4000.00	0.00	16000
Mortality rate (# calfs dying/% of calfs born)		100	100	100	100	0	0	100	0	0	100	0	600

In the second survey year, the full effect of the drought took effect on livestock. By the end of the survey period, there were only 17 cattle owned by the 12 farmers, consisting of 3 cows, 4 bulls, one ox and 9 weaners. Eight calves were born during this period, although none survived to weaning. The calving percentage shows 267%, however this is due to the mortalities of the cows that produced the calves during this period.

Figure 5.10 provides a graphical representation of monthly livestock numbers during the survey period. It can be observed that the full effect of the drought too effect from June 2015, with most livestock losses occurring in the period June to December 2015.

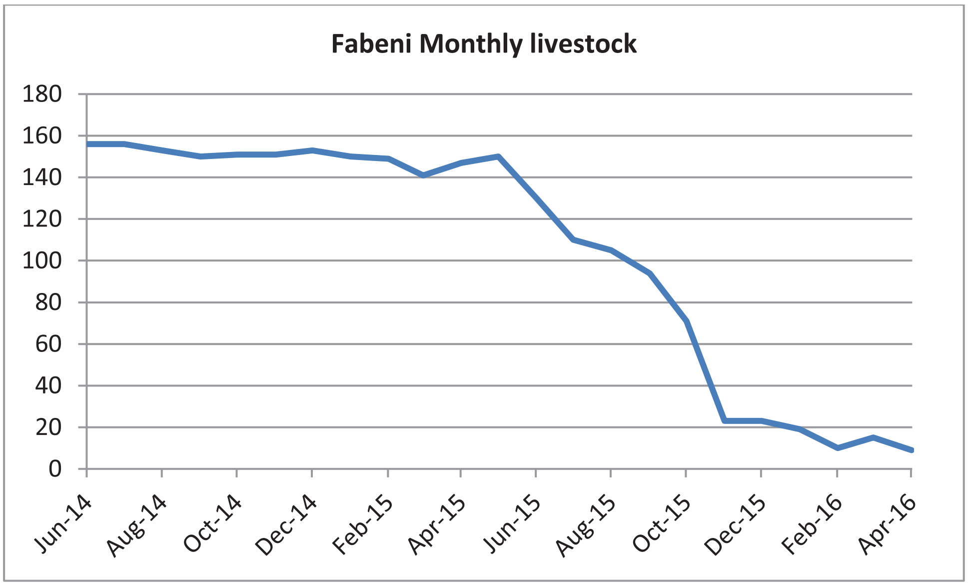


Figure 5.10: Monthly cattle counts June 2014 to April 2016

Based on prevailing prices of live sales of animals in Muden, the estimate loss in value of livestock is R418 000 (Table 5.15).

Table 5.15 Estimated value of livestock deaths due to drought for the surveyed farmers in Muden, KwaZulu-Natal

	No. of livestock (Apr 2015)	No. of livestock (Apr 2016)	No. of animals lost	Unit value (R)	Value
Cows	57	3	54	3,000.00	162,000.00
Heifers	5	0	5	2,000.00	10,000.00
Bulls	19	4	15	8,000.00	120,000.00
Oxen	11	1	10	5,000.00	50,000.00
Weaned cows	21	5	16	2,000.00	32,000.00
Weaned bulls	18	4	14	2,000.00	28,000.00
Female calves	10	0	10	1,000.00	10,000.00
Male calves	6	0	6	1,000.00	6,000.00
				Total	418,000.00

No expenditure on inputs was recorded for cattle in Muden – farmers do not spend money on livestock in this area. The farmers indicated that they dip their livestock in summer. Mdukatshani (a local NGO) also provides assistance with antibiotics when farmers require these. Farmers indicated that they do not spend much money on animal health.

Goat productivity

Given the low levels of productivity of livestock due to the prevailing drought in Muden, an analysis of goat productivity from the surveys was conducted. The summaries of these figures are provided in Table 5.16 and Table 5.17. All fifteen farmers that were surveyed owned goats. The flock structure of the 15 farmers consisted of a total of 607 goats, composed of 259 does, 3 maiden does, 45 bucks, 65 castrated bucks, 171 weaners and 87 kids in April 2015. During the periods in question, the kidding and weaning percentages were 66% and 37% respectively. A total of 77 kids died, giving a 55% mortality rate at an estimated cost of R35 500.

According to Kessler (undated), a realistic goal for a commercial goat farming operation is a kidding percentage of 175% to 200% per annum, with a mortality rate of 5% (i.e. weaning percentage of 96%). While it is acknowledged that goats are not kept by farmers in Muden for commercial production, it does provide a benchmark with which to understand current levels of goat productivity in Muden.

Between April 2015 and April 2016, the flock decreased to 528 goats, with 213 does producing 169 kids of which 113 were weaned. This gives a kidding and weaning percentage of 79% and 53% respectively. The kidding percentage from this season was higher, but mortalities of kids were higher at 67%, resulting in a weaning percentage of 53%. This represents a loss of R28 000 at a value of R500 per kid.

Expenditure on inputs was limited. Between June 2014 and April 2015, a total of R1 333 was spent on inputs, consisting of R178 on anthelmintics, R876 on antibiotics and R279 on 'other' for the three farmers who purchased inputs, the average spend per animal ranged from R4.09 to R10.49. No expenditure on inputs was recorded for the period April 2015 to April 2016.

Compared with the cattle productivity, it is clear that the goats were not nearly as badly affected by the drought, which suggests that there was sufficient browse available for them. What is also interesting is that farmers spent no money on cattle, but three farmers did spend money on antibiotics and anthelmintic for their goats, even though this livestock is considered to be the less important form of livestock for famers in Muden

Table 5.16: Goat productivity at Fabeni June 2014 to April 2015

Farmer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Summary / Total
Does	37	12	9	35	12	2	26	8	27	13	21	16	6	10	25	259
Maiden does	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	3
Bucks	6	1	5	4	1	0	3	1	3	1	8	3	1	4	4	45
Castrated kids	6	9	2	8	0	1	13	0	5	4	0	9	4	1	3	65
Weaned female kids	4	6	2	2	2	2	11	2	14	5	4	2	0	1	14	71
Weaned male kids	12	8	1	9	8	0	10	1	5	7	2	2	0	0	12	77
Female kids not weaned	12	8	2	7	5	2	9	0	0	1	0	4	4	0	0	54
Male kids not weaned	5	6	1	5	2	1	7	0	0	0	0	2	4	0	0	33
Total animals	**82**	**50**	**22**	**72**	**30**	**8**	**80**	**12**	**54**	**31**	**35**	**38**	**19**	**16**	**58**	**607**
Female kids born	10	6	2	12	2	1	15	3	14	5	6	2	2	2	10	92
Male kids born	15	2	5	8	5	1	10	4	3	6	3	9	1	3	5	80
Total kids born	25	8	7	20	7	2	25	7	17	11	9	11	3	5	15	172
Female weaned	4	5	2	2	2	1	11	2	10	2	0	2	0	1	7	51
Male weaned	12	2	1	2	4	0	9	1	2	2	0	2	0	0	7	44
Total kids weaned	16	7	3	4	6	1	20	3	12	4	0	4	0	1	14	95
Kidding percentage	68%	67%	78%	58%	100%	96%	88%	88%	63%	85%	43%	69%	50%	50%	60%	66%
Weaning percentage	43%	58%	33%	50%	50%	77%	38%	38%	44%	31%	0%	25%	0%	10%	56%	37%
Animals lost (i.e. mortalities)	9	1	4	16	1	1	5	4	5	7	9	7	3	4	1	77.00
Value of kids dying (Rands) @R500/lkid	4 500	500	2 000	8 000	500	500	2 500	2 000	2 500	3 500	4 500	3 500	1 500	2 000	500	38 500
Mortality rate (# kids dying/% of kids born)	36.00	12.50	57.14	80.00	14.29	50.00	20.00	57.14	29.41	63.64	100.00	63.64	100.00	80.00	6.67	55%

Table 5.17: Goat productivity at Fabeni April 2015 to April 2016

Farmer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Summary / Total
Does	28	16	9	20	14	3	26	7	6	13	17	14	3	18	19	213
Maiden does	0	0	0	0	0	0	4	0	0	0	4	0	0	3	8	19
Bucks	6	1	5	3	1	0	1	1	2	1	4	3	1	4	3	36
Castrated kids	6	9	2	7	0	1	13	0	3	4	0	6	2	3	0	56
Weaned female kids	14	8	2	6	4	2	13	3	2	4	7	6	0	5	3	79
Weaned male kids	12	13	1	19	11	1	14	2	3	5	8	4	0	5	12	110
Female kids not weaned	0	0	2	0	0	0	0	0	0	0	0	0	4	0	0	6
Male kids not weaned	0	0	4	0	0	0	0	0	0	0	0	0	5	0	0	9
Total animal	**66**	**47**	**25**	**55**	**30**	**7**	**71**	**13**	**16**	**27**	**40**	**33**	**15**	**38**	**45**	**528**
Female kids born	14	8	2	9	6	1	13	2	3	5	7	4	2	5	7	88
Male kids born	10	6	4	10	5	1	14	1	2	6	6	2	2	5	7	81
Total kids born	24	14	6	19	11	2	27	3	5	11	13	6	4	10	14	169
Female weaned	14	6	3	6	4	1	10	1	2	0	7	4	0	5	3	66
Male weaned	0	6	1	10	3	1	10	1	2	0	6	2	0	5	0	47
Total kids weaned	14	12	3	16	7	2	20	2	5	0	13	6	0	10	3	113
Kidding percentage	86%	88%	67%	95%	79%	67%	104%	43%	83%	85%	76%	43%	133%	56%	74%	79%
Weaning percentage	50%	75%	33%	80%	50%	67%	77%	29%	83%	0%	76%	43%	0%	56%	16%	53%
Animals lost (i.e. mortalities)	10	2	3	3	4	0	7	1	0	11	0	0	4	0	11	56
Value of kids dying (Rands) @R500/lamb	5000	1000	1500	1500	2000	0	3500	500	0	5500	0	0	2000	0	5500	28000
Mortality rate (# kids dying/% of kids born)	58%	86%	50%	84%	64%	100%	74%	67%	100%	0%	100%	100%	0%	100%	21%	67%

Marketing of livestock

In Ntshiqo, farmers pointed out that there are no formal markets for livestock. Marketing of livestock occurs informally in Ntshiqo and also in the town of Tsolo nearby. Table 5.18 shows the prices that farmers expect to receive for their livestock. These are the expected prices for live animals.

Table 5.18: Expected prices for live sales of different livestock types

Livestock type	Expected price	Comment
Cattle		
Ox - old	R7 000-9 000	A really good ox will sell for R9 000.
Ox - young	R5 000-6 000	
Heifer (ready for bull)	R5 000	
Heifer in calf	R6 000	
Cow	R6 000-7000	Should have had at least two calves to demonstrate fertility
Bull	-	Bulls are not usually sold.
Sheep		
Wethers (castrated males)	R1 200-1 300	A big one can be sold for R1 500
Does (ewes)	R600-700	The price is lower because the meat is poor
Yearling does (ewes)	R800	
Rams	-	Rams are usually not sold
Goats		
Wethers	R1 500	Closer to Kokstad where there is more bushveld, wethers are much larger and sell for R2 000
Ewe	R600-700	
Rams / Bucks	-	Bucks are usually not sold

It appears from farmers' responses that sale of livestock is dependent on personal circumstances and the number of livestock that are owned. For example one farmer who sold six sheep, ten goats and four cows had large numbers of livestock. The relative small numbers that are sold do indicate that commercial scale sale of livestock is unlikely to occur in this area due to the dispersed ownership of livestock (i.e. many farmers each owning a relatively small number of livestock).

In Muden, two farmers indicated that they had recently sold large numbers of livestock. One farmer sold approximately 20 goats, while another sold 25 goats and 4 cattle. Other farmers stated that they do not often sell as their flock size is too small. All farmers indicated that they slaughter animals for ceremonial purposes. One farmer sold four goats to supplement cash in order to purchase a cow to slaughter. When asked where they are selling their livestock the group said they sell amongst themselves. Bayer et al. (undated) state that there are three main reasons that more formal livestock marketing avenues are not used:

- ***Price:*** The prices expected by livestock owners are unlikely to be obtained at auctions. Better prices are obtained selling locally.
- ***Distance:*** Farmers often have to travel far to get their animals to an auction, local marketing involves less transport and hence less cost.
- ***Distrust:*** Rural communal livestock owners often believe that they are not getting a good deal at auctions. Farmers also feel that collusion between buyers at auctions occurs.

Livestock owners sell mostly when they are encountering poverty shocks such as illness or death in the family or a shortage of food. Livestock are also sold to cover regular costs that occur, such as school fees.

Text Box 10: The Msinga goat auction

A recent development in Msinga is the Tugela Ferry goat sale, whereby goats are auctioned on behalf of owners. The initiative is facilitated by the Department of Rural Development and Land Reform (DRDLR) and the KZN DARD. The auction is managed by AAM Livestock agents and auctioneers. The purpose is to encourage the sale of surplus livestock to reduce grazing pressure and inject cash into the local economy. None of the farmers interviewed in Muden participated in the goat sale. The sale is some distance from Muden, which is probably a constraint to marketing and sale of livestock in this manner.

The price for which the livestock is sold, according to interviewees, is determined largely by the urgency of the matter from both the buyer's and the seller's perspective. When the seller needs money urgently (e.g. for a sick person) the negotiating powers by default fall to the buyer and prices are pushed down. On the other hand when the buyer urgently needs an animal, the seller can negotiate a higher price.

Price also varies according to the types of animals sold. Young female goats (isibhuzazane) and young castrated males (umtheno) are sold at between R700 and R900, depending on the financial situation of the negotiating parties. Generally, however, young females are not sold as they are important replacement stock for the herd. If a farmer is selling young females, it indicates that the farmer is in real need. Large castrated males (intondolo) are sold for up to R1 500. Old female goats (mbuzikazi) are rarely sold but when they are, they go for about R1 000.

The sale of cattle is less common when compared with the sale of goats. Farmers often give advance warning of the intention to sell livestock at community gatherings and dipping days.

Prices vary, but according to Bayer et al. (undated) cows are sold for around R3 000, a heifer for R2 000, while a large ox will sell upwards of R5 000.

The value of croplands in the feeding of livestock

There was consensus among farmers in Ntshiqo that arable fields and homestead gardens were important for feeding livestock. This is primarily through the use of crop residues for winter feeding, but also the use of maize grain that is often used by livestock owners in Ntshiqo for supplementary feeding, especially in times of drought. Areas within fenced off fields which were not tilled but have grass are also very important sources of fodder in winter and drought periods. Farmers reported that homestead gardens were also very important as the residues from here can be set aside and controlled by the farmer to ensure that their own livestock get feed over the winter period. This is not the case with the larger fields, which become a communal resource after the harvest.

As mentioned earlier, Muden farmers indicated that cattle mostly graze relatively far from the homestead in summer, in the hills surrounding the homesteads. Winter grazing is closer to the homestead and in croplands, where crop residues are grazed. In times of drought, cattle are often moved to better grazing areas further from the homestead. Goats tend to stay closer to the homestead in summer and winter, and are allowed to graze crop residues as well.

Farmers from Fabeni pointed out that there is a serious lack of good grazing which is reducing their livestock productivity. They also highlighted that they are losing cattle because they are eating almost everything that is littered around the homesteads and that when they open the stomachs of dead cattle they find plastic, shoelaces and other waste in their stomach and dung. They believe that access to good pastures would save livestock from these dangers.

Crop fields are used for winter grazing and are very important to for livestock. Such fields are fenced off to protect the crops from livestock as proper herding is no longer practiced. In winter, maize residues and grass that has been protected within the fields are grazed. In a normal winter only cows and calves are allowed to graze there (and sometimes recently castrated bulls to allow them to recover), while in a very dry season all livestock are allowed access to the fields. In these dry periods, women are also requested not to harvest thatch to keep it for the livestock. So, in a drier season, fewer homesteads are thatched and also, hungry animals try to graze the thatched houses, causing damage. The use of the fields for lactating cows is important as they not only provide milk for the calf, but also the cows' condition improves rapidly so that they can get pregnant again. As one farmer said, "bulls don't follow malnourished cows". To sum up, farmers recognise that crop fields are very important to their livestock as they act as a fodder bank for the dry season.

Two farmers in Muden indicated that they use grain to feed animals. One used maize grain to feed chickens, while the other uses grain to feed to both chickens and goats, providing a small amount for goats every afternoon to encourage them to come home daily.

Livestock farmers pointed out that crop farmers must be encouraged to continue farming their fields as the crop residues help livestock in winter. One farmer said, “If crop farmers are discouraged by our livestock (or by other factors) then we won’t have winter feed for livestock”. Livestock owners agreed that conflicts between the two farming systems should be resolved peacefully and that crop farmers are always protected by the traditional rules – any damage caused by livestock is punishable by the traditional rules. It is the responsibility of the crop farmer to fence their fields but when livestock has damaged the crops, the livestock owner is responsible - no matter the condition of the fencing.

Discussion about crop and livestock productivity

The productivity research sought to get an understanding of productivity and the relationship between crop and livestock production systems in the Ntshiqo and Muden research sites.

Based on the interviews and focus group discussions, it was not possible to obtain absolute values in terms of crop yields or livestock production, as farmers did not keep records of their production. However there was a lot of valuable anecdotal information obtained in relation to crop and livestock production. Interviews and FGDs with farmers and livestock owners revealed that there is a very close relationship between crop and livestock production. Crop residues and other fodder (mainly grasses) growing in cropping fields are a very important grazing resource in winter. These grazing resources are particularly important for lactating cows in winter, but are opened up to all livestock in times of drought. At the same time, livestock manure is an important input into cropping systems, particularly homestead gardens.

In terms of cropping, maize is the main crop at both Ntshiqo and Muden, but in many cases, farmers intercrop with beans and squashes to increase overall production and reduce risk through diversification.

Farmers in Ntshiqo use more inputs than farmers at Muden, with the use of fertiliser being common. Farmers also commonly use tractors for land preparation in their homestead gardens and fields. In addition, herbicides are used where glyphosate tolerant maize is grown. In Ntshiqo, crops grown in the arable fields are mainly maize and the practice of intercropping with beans and squashes had declined in these lands. This may partially be attributed to the introduction of glyphosate tolerant maize through government-funded massification programmes, but other factors are also likely to play a role, such as increasing mechanisation on these fields.

In homestead gardens, intercropping is still a common practice at both sites and farmers indicated that they prefer to use own-saved seeds in these areas. Overall a greater variety of crops are grown in the homestead gardens, including potatoes and sweet potatoes as well as a variety of vegetables. This approach reduces the risk of food insecurity and crop losses through diversification. All farmers grow food for their own consumption although many also sell surplus produce. Maize grain is commonly used for feeding livestock in Ntshiqo while in Muden most of the grain produced is for home consumption.

From surveys conducted with farmers in Ntshiqo, maize yields ranged from 300-3 600 $kg.ha^{-1}$ in 2013/2014 and 580-2 600 $kg.ha^{-1}$ in 2014/2015. While there is some variation in the yield, these are within the norms to be expected for homestead production. During the period in question, reasonable rains were received in Ntshiqo. The survey also revealed that all farmers surveyed used maize grain to feed livestock and for many, this made up the largest use of grain produced, suggesting that livestock are important for farmers.

In Muden, intercropping occurs in both homestead gardens and fields. Inputs are limited – most farmers make use of OPV and own saved seeds and only a few farmers interviewed make use of mineral fertilisers. Tractors are used to a limited extent, and hand preparation and donkeys are used as draught animals for ploughing. All farmers make use of kraal manure. Food is grown in dryland fields primarily for own consumption, although in some cases surplus is sold or exchanged for other crops. There are two particularly drought tolerant crops that are regularly planted in dryland fields in Muden, namely uchokwane (Teppary bean) and amabhece (indigenous squash). That these plants are grown every year by farmers indicates that droughts occur regularly in this area. Drought in this instance can refer to either a short term period of low rainfall at a critical time in the growing season (e.g. germination), the late arrival of summer rains or a longer term protracted period of no rain.

The farming systems in the dryland areas use low levels of inputs, making as much use of local resources as possible (e.g. kraal manure and own-saved seed). Crops grown are mainly maize, sorghum, squashes (pumpkin and *amabhece*) and beans and they are usually grown in combinations as an intercropping system. This approach reduces risk of food insecurity and crop losses through diversification. Most food grown in dryland fields in Muden is for own consumption, although there is some sale and trading of crops.

Rainfall in Muden for the period in question experienced a steady decline. While 2012/2013 was a good year with above average rainfall, this declined dramatically over the 2013/2014 and 2014/2015 seasons. This is reflected in the poor crop yield data obtained in the 2013/2014 season (only three of the eight farmers harvested any crops, with a grain yield between 200 and 790 $kg.ha^{-1}$) and the complete lack of data for 2014/2015 due to farmers either not planting or experiencing complete crop failure at the surveyed sites.

Livestock in Ntshiqo is dominated by sheep, with goats and cattle making up the balance. The keeping of horses is also quite common. Livestock are continuously grazed in grasslands, which can be natural grasslands, or old croplands that have reverted back to grassland. The lack of grazing was not highlighted as a huge problem by farmers in Ntshiqo, when compared with Muden. Grazing in times of drought, however, was highlighted as a concern for farmers. Drinking water was also identified as the most critical resource in times of drought and that access to drinking water was more important than fodder, a sentiment Ntshiqo farmers shared with Muden farmers. Farmers have different strategies in responding to droughts, but most agree that watering of livestock is prioritised over crops. The supplementary feeding of livestock with maize grain is also important in winter, particularly in drought periods. Farmers do collaborate in management of livestock, but this collaboration seems to be more on controlling fires, keeping livestock out of cropping lands and sharing ideas in relation to herding and managing livestock. None of the respondents referred to cooperation in terms of actual herding of livestock.

A survey of livestock in Ntshiqo revealed that in 2015 the general flock structure of the 16 farmers, who collectively own a total of 864 sheep, was composed of 287 ewes, 143 maiden ewes and 20 rams. From May 2014 to June 2015, the collective flock achieved a lambing and weaning percentage of 98% and 76% respectively. Between May 2015 and June 2016, the flock increased to 1001 sheep and had a lambing and weaning percentage of 79% and 71% respectively, somewhat lower than the previous season. Farmers spent money on inputs, R35 328 in 2014/2015 and R14 400 in 2015/2016, which suggests that they see value in investing in their sheep and have the resources to do so.

In Muden, grazing of livestock is difficult for farmers as there is a shortage of fodder most of the time. The lack of grazing is, according to farmers, the greatest factor affecting the productivity of livestock. However for the survival of livestock, drinking water was identified as the most critical resource in times of drought and that access to drinking water was more important than fodder. All households own goats and many own cattle – these are the two most important types of livestock that are kept. Farmers were aware of the importance of rainfall in fodder production and in turn the productivity of livestock. Most livestock is traded locally among farmers and prices are negotiated between the buyer and seller. Prices received are generally higher than would be obtained at livestock auctions, according to farmers.

Croplands are critically important fodder resources in winter, particularly for lactating cows with calves. In periods of drought, all livestock are allowed into the fields. All farmers agreed that dryland cropping areas were important for livestock.

Farmers also seem to have limited support in terms of developing their agricultural capabilities, with most support coming from NGOs, although some farmers indicated that they did receive some information from the Department.

Livestock play a central role, although there are no formal grazing management systems and no herders employed to take care of livestock. Because livestock are normally sold only in response to household crises (e.g. death, illness) or to cover regularly recurring costs (e.g. school fees), grazing pressure remains high even in dry periods as farmers do not sell livestock in response to drought. In good years, most goats produce twins and a high percentage of cows produce and wean calves. In dry years, low conception rates are common and production is low.

In response to water crises, livestock farmers also use different strategies – some rent land for emergency grazing, while others move their livestock to distant grazing lands. Some simply make sure that their livestock have access to water.

Cattle numbers in Muden were devastated by the recent drought. Between April 2015 and December 2015 the number of cattle owned by 11 of the 15 farmers participating in the survey who kept cattle had declined from 147 animals to 17. The 2014/2015 season showed a calving percentage of 70% which is reasonable for a communal herd. However, the weaning rate was only 37% which suggests that the drought was already starting to affect livestock. On the other hand, goats were more resilient. For the 15 farmers surveyed, there were 607 goats in April 2015 and the flock size only dropped to 528 goats by April 2016.

The research conducted to evaluate current levels of productivity at the two research sites has provided information on both crop and livestock productivity. Reasonable levels of production and productivity were observed from surveys in Ntshiqo and can be considered representative of benchmark productivity in the areas. However in Muden, the drought conductions that started in 2013 has had a substantial impact on both crop and livestock production. The levels of production observed during the survey period will not be an accurate reflection of productivity in an average year. Nevertheless, the research into productivity provides a rich picture of the production systems used by farmers at the two research sites as well as challenges that they face.

5.3 Results of cropping research: Ntshiqo, Eastern Cape (Site 1)

The overall aim of this experiment was to determine the effect of rainwater harvesting and conservation (RWH&C) on maize yields of the rural farmers of Ntshiqo, Eastern Cape. The hypothesis was that the RWH&C would perform better the current cultivation practice and improve maize yields in this area. The experiment took place over a period of three growing seasons in 2013/14, 2014/15 and 2015/16. The yield response indicators (grain yield, biomass and harvest index) are summarised and presented in Table 5.20 and Figure 5.12 below.

5.3.1 Yields from the RWH&C demonstrations

The outcomes of the crop yields for the three growing seasons are presented below and summarised graphically in Figure 5.12 and Figure 5.13

2013/14 growing season

Findings from this study show that out of four farmers (Quvile, Sokhombela, Mjali and Madosini) that participated on the demonstration in this season, RWH&C showed a positive effected on grain yield at with two farmers (Quvile and Sokhombela). The RWH&C resulted in a 51% (treatment: 7.83 ton/ha and control: 5.18 ton/ha) and 61% (treatment: 2.01 ton/ha and control: 1.25 ton/ha) grain yield improvement compared to the control (Figure 5.12). The other two farmers (Mjali and Madosini) experienced a decline in grain yield where yield decreased by 42% (treatment: 2.37 ton/ha and control: 4.40 ton/ha) and 44% (treatment: 3.38 ton/ha and control: 1.88 ton/ha) compared with the control.

With respect to final biomass recorded, the results show that RWH&C had a negative impact of biomass accumulation (i.e. stover) at Madosini, Mjali and Sokhombela (Table 5.20). There was more biomass accumulation on the control than the treatment. With the exception of Quvile, biomass declined by 61, 57 and 19% respectively. Findings from Quvile show that there was a slight improvement on biomass as a result of RWH&C.

Interesting findings regarding the harvest index were also observed. Although the control showed superiority with respect to grain yield and biomass at most instances; harvest index (HI) showed a reverse trend (Table 5.19). This suggests that the RWH&C treatments yielded a higher amount of grain per plant compared with the across all sites.

Table 5.19: Maize grain yield, biomass and harvest index responses to RWH&C in 2013/14

Name of site	Sample	Grain yield (ton/ha)	Biomass (ton/ha)	Harvest Index (%)
Madosini	**Control**	3.38	10.68	31.61
	RWH&C	1.88	4.14	45.30
Beya	**Control**	Did not participate		
	RWH&C			
Mjali	**Control**	4.40	18.72	23.48
	RWH&C	2.37	7.97	29.79
Sokhombela	**Control**	1.25	10.89	11.47
	RWH&C	2.01	5.33	37.79
Quvile	**Control**	5.18	21.17	24.45
	RWH&C	7.83	22.70	34.48

2014/2015 growing season

The results obtained from this season's planting showed that RWH&C improved Madosini' and Mjali's grain yield from 1.47 to 4.01 ton/ha and 3.98 to 6.61 ton/ha respectively, compared with the control. This was a complete turnabout of events when comparing these results to what was observed in the previous season. In 2013/2014 both these farmers experienced a grain yield decline from RWH&C compared to control. Results from Sokhombela and Beya (Figure 5.13) showed slightly higher yields in the RWH&C treatment compared with the control, where the grain yield improved slightly from 3.19 ton/ha to 3.55 ton/ha and 4.41 to 4.58 ton/ha respectively. Quvile's grain yield results showed that the control was superior to the treatment by 25% (Figure 5.12). Seeing that results four out of five farmers show that RWH&C improved gain yield, we can be confident about this trend.

Figure 5.11: Mrs Gloria Quvile (centre) showing off a cob with Mr Nongcawula of the Eastern Cape Department of Rural Development and Agrarian Reform (left) and Ms Nokulunga Gasa of the INR (right)

Results from Madosini, Beya and Mjali show that biomass accumulation on the control was higher compared to the treatment. Biomass accumulation showed no positive response to RWH&C, it was observed to be 23% (treatment: 6.94 ton/ha and control: 9.03 ton/ha); 42% (treatment: 8.86 ton/ha and control: 15.30 ton/ha); and 16% (treatment: 15.14 ton/ha and control: 17.92 ton/ha) higher than the treatment (Table 5.20). However the HI shows an opposite response, in these very same sites, harvest Index was found to respond positively to RWH&C. The HI of Madosini, Beya and Mjali improved from 16.29 to 57.8%; 28.8 to 51.67 and 22.21 to 43.69% respectively. Quvile's HI is abnormally high in 2014/15, which is likely to be from an error in measuring the biomass yield.

Table 5.20: Maize grain yield, biomass and harvest index responses to RWH&C in 2014/15

Name of site	Sample	Grain yield (ton/ha)	Biomass (ton/ha)	Harvest Index (%)
Madosini	**Control**	1.47	9.03	16.29
	RWH&C	4.01	6.94	57.78
Beya	**Control**	4.41	15.30	28.84
	RWH&C	4.58	8.86	51.67
Mjali	**Control**	3.98	17.92	22.21
	RWH&C	6.61	15.14	43.69
Sokhombela	**Control**	3.19	5.83	54.72
	RWH&C	3.55	12.68	27.99
Quvile	**Control**	5.87	6.35	92.41
	RWH&C	4.41	6.16	71.61

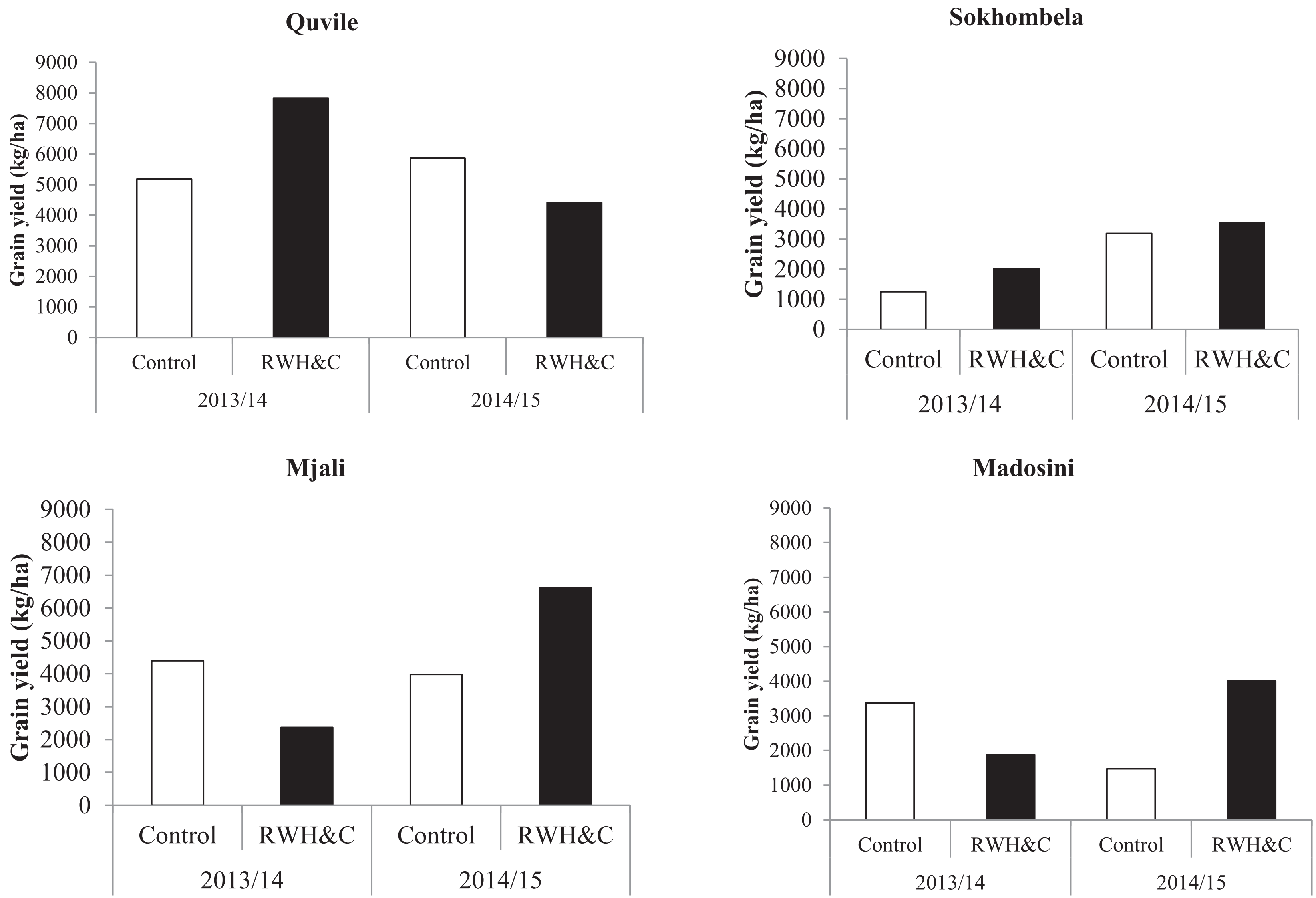


Figure 5.12 Grain yield responses to RWH&C at Quvile, Sokhombela, Mjali and Madosini's garden at Ntshiqo in 2013/14 and 2014/15

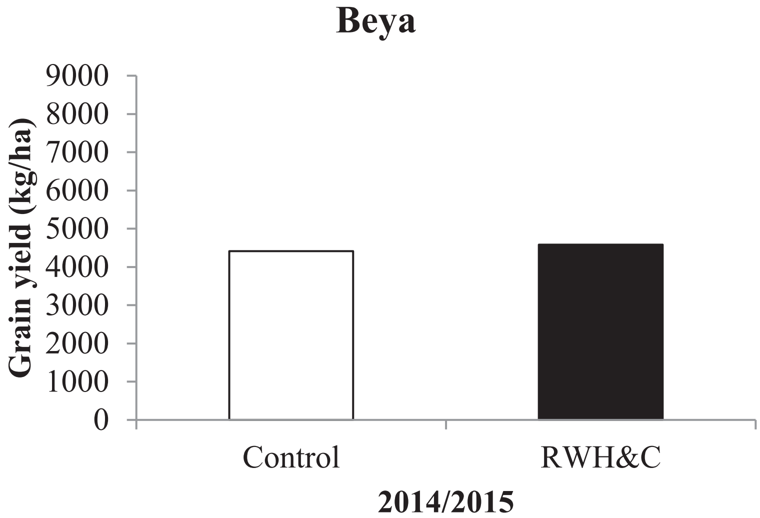


Figure 5.13 Grain yield response to RWH&C at Beya's garden in 2014/15

2015/2016 growing season

Land preparation was undertaken during the last week of November in 2015 upon receiving about 17 mm of rainfall and planting took place on the 3-4th of December. The first site visit to assess germination was conducted on 11 of January 2016. There was very poor germination due to lack of rainfall as shown in Figure 5.14, pictures which were taken on 11 January 2016. At Mjali's garden there was no germination, while less than 1% germination was observed at Beya's garden. Even the hardy, drought tolerant plants such as pumpkins and squashes were not performing. This was observed at Madosini's garden and this showed how critical the timing of rainfall is when planting crops. Other farmers in Ntshiqo had ploughed their gardens and they were waiting for rains before planting.

Figure 5.14: RWH&C contours 2014/2015

The research team had a meeting with the participating farmers to come up with a way forward. The farmers suggested that there should be not replanting of maize because that would be a waste of seed, given how late the season was, and proposed that a short season crop was explored. As a result of these discussions, It was decided that sugar beans be planted in February.

The rainfall data shows that there was very low rainfall received in November and December 2015 (Figure 5.1) and hence poor germination. The farmers also highlighted that rainfall was not evenly distributed, there was too much micro climate variations. For example it would rain at Tsolo town and 10 km away in the villages it would be dry. So the data might show that higher rainfall was received in January and February, however, it did not necessarily occur at Ntshiqo.

Sugar beans were planted in February 2016. However, there were no results of value obtained from these yields due largely to lack of weeding by the farmers during the early stages of plant growth.

5.3.2 Soil water content (SWC)

The gravimetric soil water content samples collected in 2013/2014 season were taken at shallow depths (1-10, 10-20 and 20-30cm) primarily for the purpose of evaluating changes in soil chemical and biological properties. A more comprehensive approach was, however, adopted in subsequent seasons, where samples were taken at 30 cm intervals down to effective rooting depth. Gravimetric

SWC was also collected at different locations within the demonstrations - in the runoff collecting area, above the contour and below the contour (Figure 3.6). The SWC results obtained in 2014/2015 growing season show a peak in SWC during the reproductive stage for both RWH&C and the control. The soil samples were taken on 17 of March 2015 and there were rainfall events prior to this day and hence the peak in soil water content at reproductive stage (Figure 5.15).

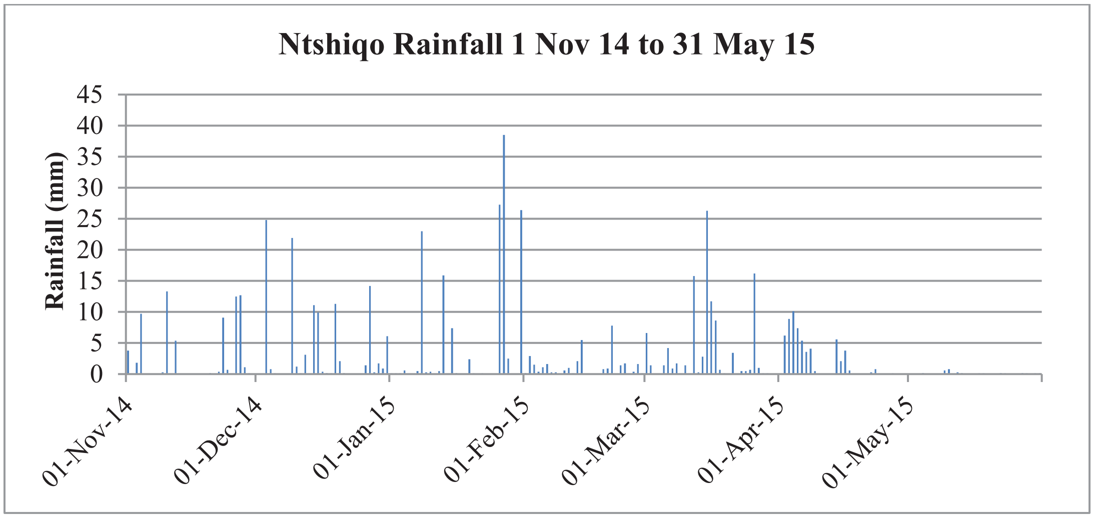


Figure 5.15: Daily Rainfall at Ntshiqo from Nov 2014 to May 2015

Figure 5.16 to Figure 5.20 show the soil water content for the five farmers at the depths of 30cm and 60cm. These are discussed in more detail below.

Quvile

In 2014/2015, the results show differences between the control and RWH&C treatment (above ridge, below ridge and runoff collecting area) at soil depth of 30 cm and 60 cm. There was a marked difference between the control and RWH&C at planting for both soil depths (30 cm and 60 cm). Below the ridge had the highest SWC followed by runoff and above ridge, and the control showed the least. In principle SWC increases down the soil profile, there was a slight increase in overall SWC at 60 cm soil depth on the RWH&C treatment but the control showed a decline in SWC. The SWC results from this site also show that, in general there was more water found below ridge. In most cases the control had lower SWC compared to the treatment (Figure 5.16).

Sokhombela

In 2014/15, for both soil depths (30 cm and 60 cm); the control manifested a competitive SWC compared to above ridge for most growth stages. Below ridge and on the runoff collecting area there was generally a higher SWC compared to the control and above ridge (Figure 5.17).

Mjali

In 2014/2015, from planting to reproductive stage, there was higher SWC below ridge at 30 cm soil depth. The general trend also shows that there was higher SWC on the RWH&C treatment compared to the control. However, interestingly at harvest, there was more water observed at both depths in the control (Figure 5.18).

Madosini

In 2014/2015, the overall results at planting show that RWH&C performed better with respect to SWC (Figure 5.19). At 30 cm soil depth the runoff collecting area showed the highest SWC compared to other positions in the treatment. The soil water content above and below ridge did not show substantial differences. During the establishment and vegetative stage, below ridge showed the highest water content compared to the above, runoff and control. During the reproductive stage, there was no distinct difference between treatment and control while at harvest there was less soil water on the treatment compared to the control. At 60 cm soil depth, the trend suggests that there was higher SWC in the treatment compared to control at most growth stages (Figure 5.19).

Beya

In 2014/2015, the results presented in Figure 5.20, show that there was lower SWC at planting at the 30 cm soil depth in the control compared to the RWH&C treatment. This pattern was maintained through the vegetative and reproductive stage. However, the control showed higher SWC at harvest. At 60 cm soil depth, the treatment mainly showed higher soil water content during the vegetative and reproductive stages of crop growth.

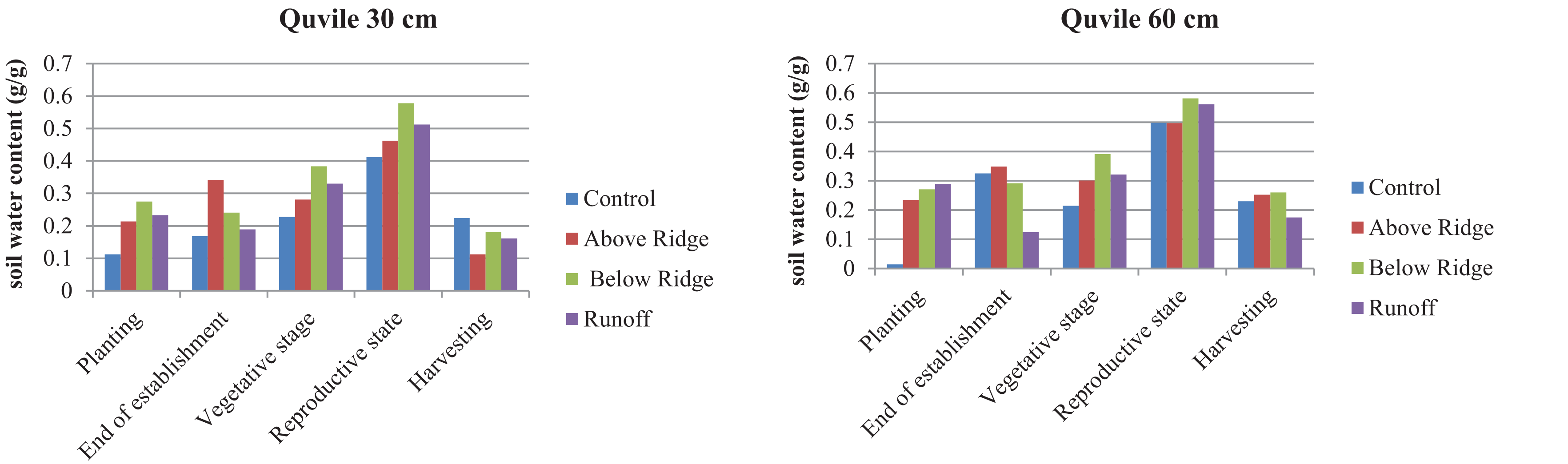


Figure 5.16: Soil water content at 30 and 60 cm soil depth observed at Quvile's garden in 2014/2015.

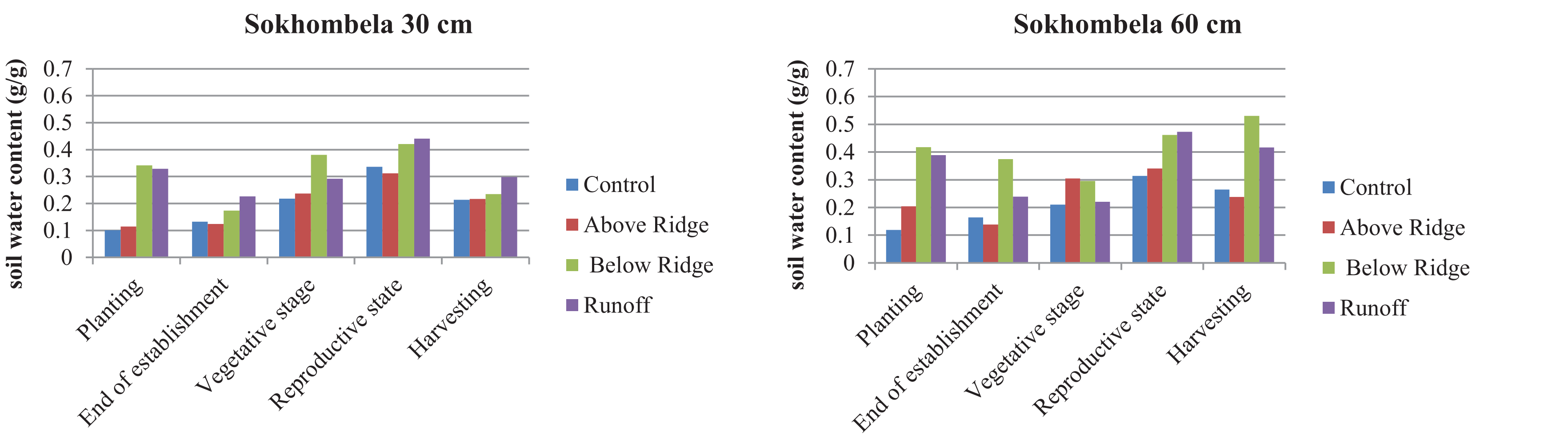


Figure 5.17: Soil water content at 30 and 60 cm soil depth observed at Sokhombela's garden in 2014/2015

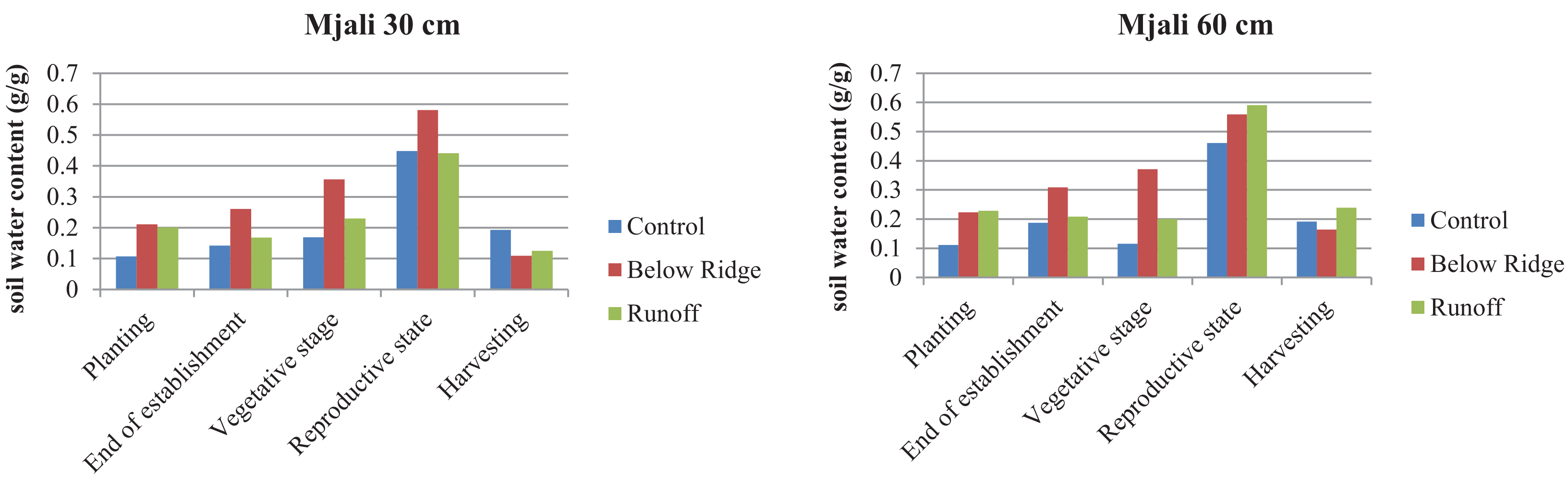


Figure 5.18: Soil water content at 30 and 60 cm soil depth observed at Mjali's garden in 2014/2015

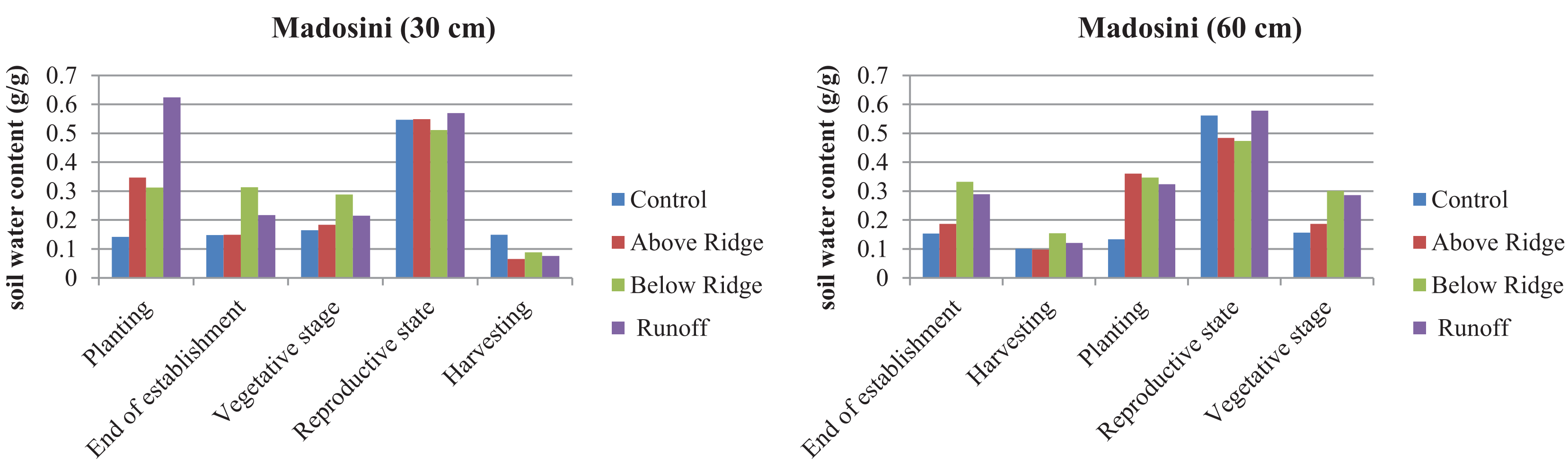
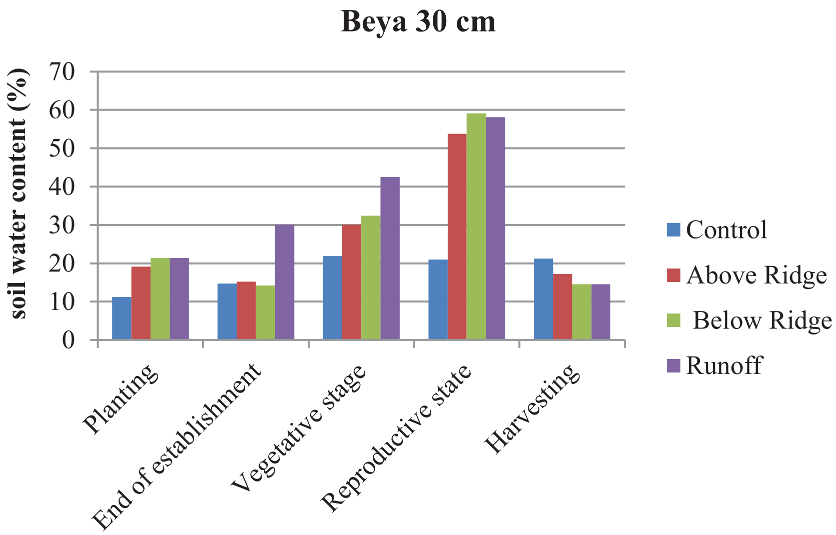


Figure 5.19: Soil water content at 30 and 60 cm soil depth observed at Madosini's garden in 2014/2015



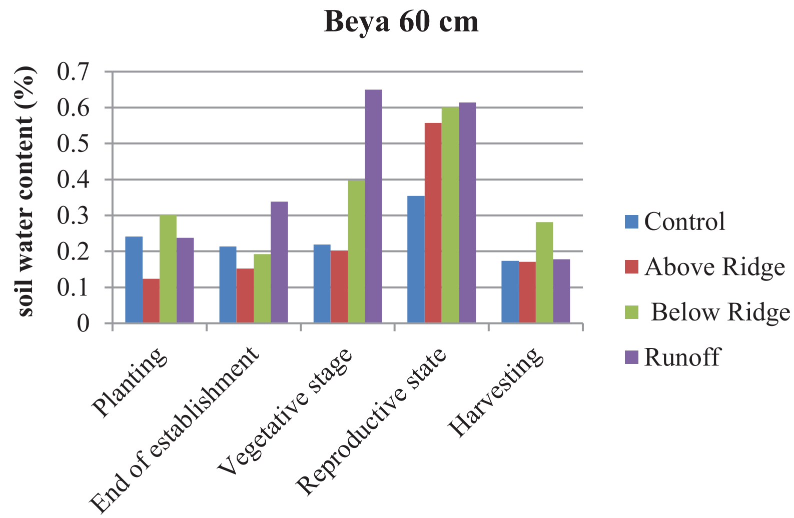


Figure 5.20: Soil water content at 30 and 60 cm soil depth observed at Beya's garden in 2014/2015

Generally it was observed that there was higher SWC associated with the RWH&C treatment compared to the control. However, in most cases, this did not always translate to higher yields in the RWH&C treatment.

Discussions with farmers were conducted to determine what their opinions were for the seemingly contradictory outcome of variable performance between the treatment and control, while there was consistently higher soil water in the RWH&C treatment compared with the control. A number of reasons were attributed for this. Firstly, in the 2013/2014 growing season, high rainfall occurred about a week after germination. This resulted in ponding of water at the base of the RWH&C contours and resulted in low germination, particularly at the Mjali and Madosini sites.

Interestingly, in spite of hail damage from a storm that occurred on 14 December 2014, where both the Mjali and Madosini sites were damaged, the RWH&C treatments resulted in higher yields compared with the controls (Figure 5.12).

Figure 5.21: Signs of waterlogging in 2013/2014 season (left) and hail damage in 2014/2015 season (right)

An additional factor influencing yield was that of weeding. A number of farmers did not properly weed their homestead gardens and consequently the crops did not perform well as a result.

5.4 Results of cropping research: Muden, KwaZulu-Natal (Site 2)

The overall aim of this experiment was to determine the effect of RWH&C on maize yields of the rural farmers of Muden, KwaZulu-Natal. The hypothesis was that the RWH&C treatment would perform better than the current cultivation practice and would improve maize yields in this area. The experiment took place over a period of three growing seasons, namely 2013/14, 2014/15 and 2015/16.

5.4.1 Yields from the RWH&C demonstrations

The outcomes of the demonstrations in terms of crop yields for the three growing seasons are presented below and discussed.

Fabeni

2013/2014 growing season

At Fabeni, contours were established and crops were planted in November 2013. Germination of maize was good, with more than 80% emergence. Initially there was a challenge with crows removing the germinating seed and therefore replanting was required. However, a good stand of crops had been achieved by the end of December. However, no rain fell at Fabeni for the month of January, and as a result, there was total crop failure and measurements of yield and water use were abandoned for this season.

Figure 5.22: Crop failure at Fabeni, Muden due to lack of rain in January 2014

2014 / 2015 growing season

Land preparation and planting took place between 15 and 20 December 2014. Normally, planting is undertaken in November, but with no rains during this month, planting was delayed. Initial germination and emergence were promising, although gap-filling was again required due to crow damage. However, as the growing season progressed, lack of rainfall resulted in crop failure at this site. The rainfall data obtained from the AWS installed at the site was compared to the median annual rainfall according to the Bioresource data for the area (Camp, 1997). The comparison showed that there was a great reduction in rainfall during this season and this might have been the reason for crop failure (Figure 5.3).

<u>2015/2016 results</u>

In this season, the demonstrations were only established on 8 January 2016 because there were very high, concentrated rainfalls in December and it became too wet to prepare land and plant. At the beginning stages of crop growth, the crop was looking very good, however the weather situation worsened at the end of vegetative stage towards flowering. The daily temperatures became too high and there was very limited rainfall. A comparison of promising crop growth in the early stages with subsequent crop failure is provided in Figure 5.23 and Figure 5.24.

Figure 5.23: Condition of the maize crop at knee height stage at Fabeni, Muden in February 2016

Figure 5.24: Maize crop showing signs of water stress at vegetative stage at Fabeni, Muden in March 2016

Mxheleni

At Mxheleni, the RWH&C treatment was found to improve grain yield compared with the control (current practice). The results presented here only show 2013/14 and 2015/16 seasons; there was a total crop failure in 2014/15 in both the treatment and control, hence no yield was recorded. There was a marked improvement in grain yield as a result of RWH&C: 1.26 $tons.ha^{-1}$ was achieved in comparison with 0.96 $ton.ha^{-1}$ in the control. In 2015/16, the overall yields improved, and there was a 20% yield gap between the treatment and control, with RWH&C maintaining superiority over the control.

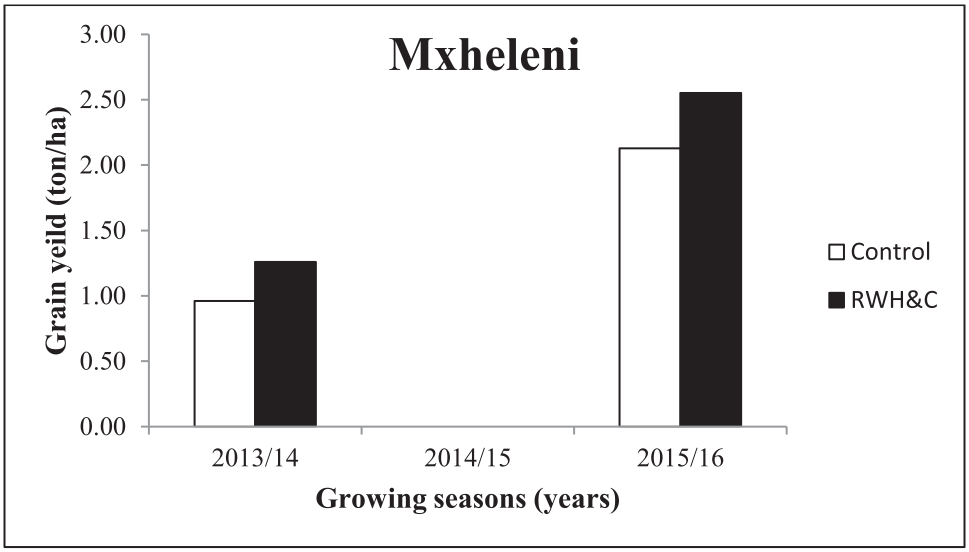


Figure 5.25: Maize grain yield responses to RWH&C at Mxheleni, Muden

These observations suggest that farmers are benefitting in the sense that there will be more maize produced. These farmers farm for home consumption and they normally sell the surplus, therefore improved yields might lead to more income generating opportunities.

One of the reasons for the high variation in yield was the substantial loss of plants in both the treatment and control, resulting in lower plant populations than were originally planted. In light of this it was decided to evaluate any other observed differences. A notable difference was that of weight of maize grain per cob, which was consistently higher in the treatment when compared with the control across all sites.

The stone contour bunds at Mxheleni proved to be effective in not only harvesting rainwater, but were also particularly good at controlling erosion. A substantial amount of soil was observed to build up behind the stone contour bunds, as shown in Figure 5.26. Measurements were taken of the depth of soil deposited behind the stone contour bunds, the distance to which deposition extended above the stone contour and the length of the contour. Applying the formula for the volume of a wedge ($^1/_2$ x base x perpendicular height x length), it was possible to estimate the volume of soil deposited behind the bunds.

The volumes of soil deposited behind the three bunds were 0.98, 1.06 and 0.31 m^3, giving a total volume of 2.35 m^3 that would have been eroded from the site had these contours not been in place. This suggests that stone contours, in addition to the RWC&C, have an important role to play in preventing soil erosion.

Figure 5.26: Sediment deposition behind stone contour bunds at Mxheleni, Muden

In discussion with the Mxheleni women's group, where the benefits of the stone contour bunds were demonstrated through the improved crop yields and the trapping of sediment, it was queried whether this practice would be extended to other parts of the garden. The response received was that the group did observe the benefits associated with the new practice, but the amount of labour required to build the contours was considered a key constraint. It must be understood that the members of this group are women over the age of 50, and thus this would be very difficult work for them. When asked whether other, younger family members would be prepared to assist, it was noted that school going children had very little time to contribute to this work due to school commitments. It was also indicated that young adults were unwilling to do this type of work without some form of payment which the group would be unable to provide. This suggests that some form of grant or external funding would be required to expand this practice, in spite of the clear yield benefits associated with the stone contour bunds.

5.4.2 Soil water content

Due to the crop failure at Fabeni, the focus for the KZN site is on the Mxheleni site. At planting, there was very low soil water content compared to the other growth stages, it was generally below 0.05 g/g for both treatment and control (Figure 5.27). The runoff collecting area and below ridge showed the lowest SWC, and the above ridge and control showed almost similar SWC. There was a noticeable improvement during the reproductive stage and maturity. In overall at this stage, the treatment has higher SWC compared to the control. The runoff collecting area had the highest SWC followed by below ridge and above ridge and the lastly control showed the least SWC (Figure 5.27). Opposing observations were made at maturity; where the control showed the highest SWC compared to the treatment.

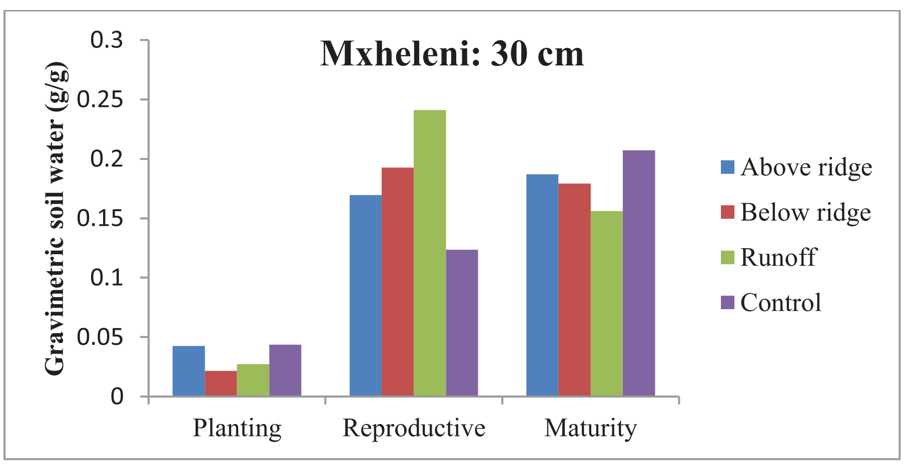


Figure 5.27: Soil water content observed at Mxheleni in 2015/2016 at 30 cm soil depth

The higher yields obtained in 2015/16 may be due to the soil water content (SWC) improvement observed during the reproductive stage.

5.5 Modelled crop water productivity

This section presents the outcomes of the modelling exercise using AquaCrop. Modelling was performed to evaluate the effect of RWH&C on yields and crop water productivity. The modelled results are presented and compared with the observed yields and SWC.

5.5.1 Ntshiqo, Eastern Cape

With respect to yield parameters, there were substantial differences between the observed and the simulated results across all sites. The simulated yields were higher than the observed yields across all the research sites (Table 5.22).

Comparison of simulated and observed yields

A comparison of the simulated and observed yields for the three growing seasons is provided below.

2013/14 growing season

With respect to grain yield the observed results indicate that the RWH&C treatment achieved higher yields than the control at only two of the five sites: Sokhombela (treatment: 2.01 ton.ha^{-1} versus control: 1.25 ton.ha^{-1}) and Quvile's (treatment: 7.83 ton.ha^{-1} versus control: 5.18 ton.ha^{-1}. However according to the model, grain yield, biomass and harvest index of the RWH&C are only marginally higher than those of current practice. The interesting observation made though was that across all sites, RWH&C improved water productivity by 9, 7, 12 and 9% at Madosini, Mjali, Sokhombela and Quvile respectively.

2014/2015 growing season

In this planting season, there was still no particular trend with respect to the effect of RWH&C on observed yield parameters. However, the simulated results showed in increase average grain yield from 5.65 to 7.4 ton/ha (control) and 6.25 to 8.5 ton/ha (RWH&C). AquaCrop predicted a grain yield improvement of 14.23 to 15.68% with RWH&C compared with the control at all sites (Table 5.22); while biomass accumulation was also predicted to improve by between 14.22 and 15.77% in the RWH&C treatment compared with the control. Two sites (Madosini and Sokhombela) showed a small difference between treatment and control (RWH&C = 49%; Control = 50%). The comparison of simulated and observed results show that although the model predicted higher values with respect to yield, the trend shown by the modelled data is in agreement with observed results. Observed results showed RWH&C improves grain yield in 50% of cases at Ntshiqo. Crop water productivity was improved with application of RWH&C at all sites. There was a percentage increase on crop water productivity of 11.7, 12.2, 11.7, 14.5 and 9.5% at Madosini (Treatment: 1.81 kg.m^{-3}; control: 1.62 kg.m^{-3}), Beya (Treatment: 1.75 kg.m^{-3}; control: 1.56 kg. m^{-3}), Mjali

(Treatment: 1.81 kg.m^{-3}; control: 1.62 kg.m^{-3}), Sokhombela (Treatment: 1.81 kg.m^{-3}; control: 1.58 kg.m^{-3}) and Quvile (Treatment: 1.73 kg.m^{-3}; control: 1.58 kg.m^{-3}) respectively (Table 5.22).

2015/2016 growing season

No yield data from this season was obtained and it has therefore been excluded from this analysis.

Soil water content

The simulated soil water content results of 2013/2014 season showed no differences between RWH&C and the control. The 2014/2015 results are presented on Figure 5.28 and Figure 5.29, and Table 5.21 below. With an exception of Quvile and Sokhombela; the SWC at Mjali, Madosini and Beya was predicted to be almost the same for the control and treatment and this trend was consistent with soil depth. There was an increase in SWC with increasing depth for both the control and treatment (Figure 5.28); however the RWH&C showed higher SWC compared to the treatment. At 30 cm soil depth, for three initial stages, the treatment always maintained a higher SWC than the control.

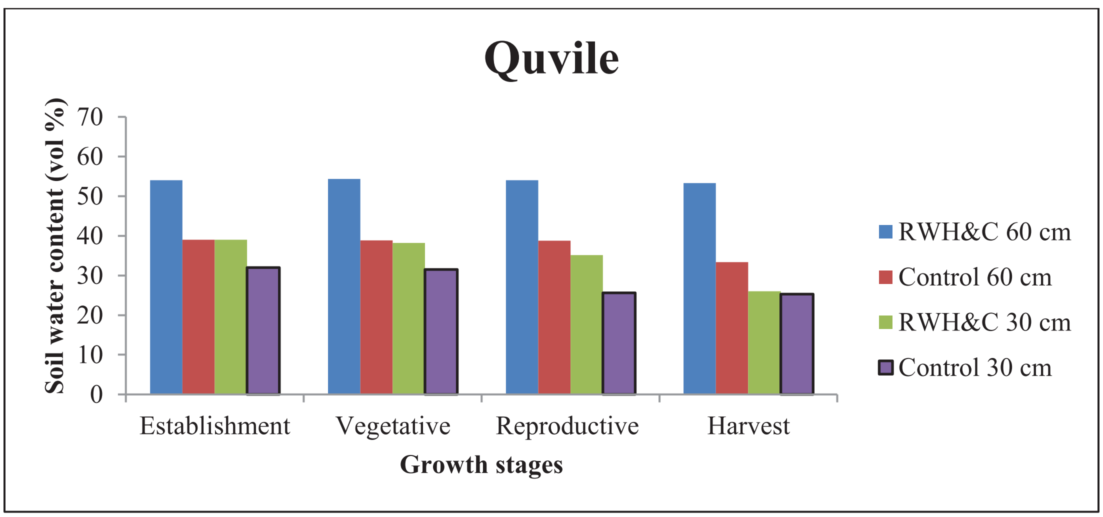


Figure 5.28 Simulated Soil water content for Quvile at Ntshiqo in 2014/2015

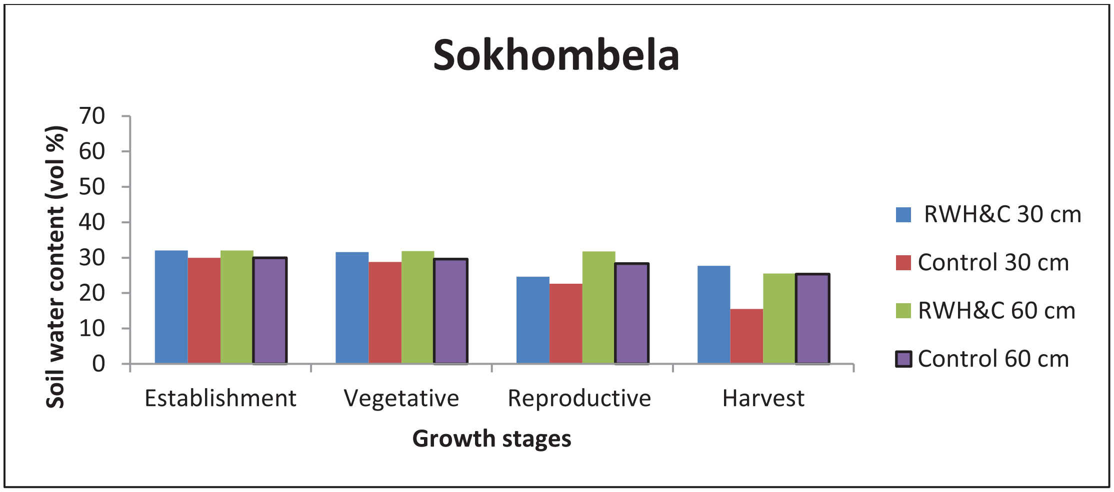


Figure 5.29 Simulated soil water content for Sokhombela at Ntshiqo in 2014/2015

For Sokhombela, there were slight differences between RWH&C and control with respect to simulated SWC at establishment, vegetative and reproductive stages across both soil depths (Figure 5.29). The trend observed at Quvile, where SWC increases with soil depth did not manifest significantly at this site. At harvest, there was a marked difference between RWH&C and control at 30 cm soil depth; with RWH&C showing superior SWC than control (Figure 5.29).

Table 5.21 Simulated soil water content for Ntshiqo, Eastern Cape in 2014/2015

Depth		**30 cm**		**60 cm**	
Site	**Growth stage**	**RWH&C**	**Control**	**RWH&C**	**Control**
Mjali	At Planting	22.0	22.0		14.7
	Establishment	22.0	22.0	22.0	22.0
	Vegetative	21.4	21.4	21.8	21.9
	Reproductive	14.6	15.1	21.8	21.8
	Harvest	17.5	16.8	14.6	15.7
Madosini	At Planting	22.0	22.0	25.7	25.7
	Establishment	22.0	22.0	32.0	32.0
	Vegetative	21.4	21.4	32.0	32.0
	Reproductive	15.1	15.1	31.8	31.8
	Harvest	16.8	16.8	26.6	26.6
Beya	At Planting				
	Establishment	39.0	39.0	39.0	39.0
	Vegetative	36.8	37.2	38.8	39.1
	Reproductive	28.0	29.9	37.8	39.0
	Harvest	25.5	24.7	34.2	36.3

5.5.2 Mxheleni – Muden, KwaZulu-Natal

According to the model predictions, the implementation of RWH&C improved crop water productivity at Fabeni and Mxheleni (Table 5.23). For Fabeni, there was no full comparison of observed and simulated results due to frequent incidences of total crop failure. The model did not perform well with respect to predicting crop's performance at Fabeni. It predicted reasonable maize yields while in reality there was total crop failure for all the growing seasons (Table 5.23). The model predictions show that application of RWH&C would have improved water productivity by 90%, 58% and 38% in 2013/2014; 2014/2015 and 2015/2016 respectively.

At Mxheleni there was a 31% improvement in grain yield in 2013/14 season as a result of RWH&C while the model predicted a 37% improvement. In this instance, the model performed well, the predictions were not far off in terms of the observed data. However, in terms of the actual yield values, the model over estimated yield predictions when compared with observed data. It is highly unlikely that rural subsistence farmers would obtain such yields. Water productivity was estimated to improve with the application of RWH&C (Table 5.23).

Table 5.22 Yield parameters and water productivity of maize over two growing seasons at Ntshiqo

Site	2013/2014							2014/2015						
	Observed			Simulated				Observed			Simulated			
	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Water productivity ($kg.m^{-3}$)	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Water productivity ($kg.m^{-3}$)
Madosini control	3.38	10.68	31.61	5.40	10.26	53.10	1.49	1.47	9.03	16.29	7.33	14.67	50.00	1.62
Madosini RWH&C	1.88	4.14	45.30	6.10	11.58	52.70	1.63	4.01	6.94	57.78	8.48	16.98	49.90	1.81
Beya control	Not planted							4.41	15.30	28.84	7.35	14.70	50.00	1.56
Beya RWH&C	Not planted							4.58	8.86	51.67	8.45	16.92	50.00	1.75
Mjali control	4.40	18.72	23.48	5.44	10.26	53.10	1.49	3.98	17.92	22.21	7.38	14.77	50.00	1.62
Mjali RWH&C	2.37	7.97	29.79	5.96	11.38	52.40	1.60	6.61	15.14	43.69	8.55	17.10	50.00	1.81
Sokhombela control	1.25	10.89	11.47	6.00	12.12	49.50	1.51	3.19	5.83	54.72	7.42	14.83	50.00	1.58
Sokhombela RWH&C	2.01	5.33	37.79	6.83	13.52	50.50	1.69	3.55	12.68	27.99	8.48	16.98	49.90	1.81
Quvile control	5.18	21.17	24.45	5.72	11.11	51.50	1.49	5.87	6.35	92.41	7.40	14.80	50.00	1.58
Quvile RWH&C	7.83	22.70	34.48	6.10	11.58	52.70	1.63	4.41	6.16	71.61	8.45	16.90	50.00	1.73

Table 5.23 Yield parameters and water productivity over three growing season at Muden

Site	2013/2014							2014/2015							2015/2016						
	Observed			Simulated				Observed			Simulated				Observed			Simulated			
	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Water productivity ($kg.m^{-3}$)	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Water productivity ($kg.m^{-3}$)	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Grain yield ($t.ha^{-1}$)	Biomass ($t.ha^{-1}$)	Harvest Index (%)	Water productivity ($kg.m^{-3}$)
Mxheleni Control	0.96	NR	NR	5.93	11.84	50.10	1.28	Crop failed			4.76	9.79	48.60	1.24	2.13	1.42	149.69	4.46	9.55	48.60	1.38
Mxheleni RWH&C	5.02	NR	NR	8.12	16.28	49.90	1.54				5.91	12.23	48.30	1.44	2.55	3.18	80.24	5.23	11.30	46.30	1.51
Fabeni control	Crop failed			3.07	7.63	40.10	0.70	Crop failed			5.97	2.30	38.80	0.59	Crop failed			2.40	6.06	39.60	0.84
Fabeni RWH&C				6.91	13.84	50.00	1.33				3.78	7.81	48.50	0.93				3.57	7.39	48.30	1.17

NR = not recorded

5.6 Comparing observed and simulated water productivity and evapotranspiration

With the data obtained from the modelling and the field research observed and modelled water productivity (WP) and evapotranspiration (ET) was compared in order to determine how the modelled values compare with observed values.

Water productivity was calculated using the following equation:

WP = P x Ya/ETa, where

Ya is the actual harvested yield ($kg.ha^{-1}$)

ETa is the actual evapotranspiration ($m^3.ha^{-1}$)

P Price received, which is a function of quality and other market factors. This variable was set to one as produce was not sold by the farmers in question, and quality of the crop could not be determined.

ET – Evapotranspiration (ET = P + I + R + D ± ΔSWC), where

P – Precipitation

I – Irrigation (set at zero as no irrigation was applied)

R – Runoff (set at zero as slopes were generally gentle, allowing for infiltration)

D – Drainage (set to zero under rainfed conditions, there is generally no deep drainage because soils generally don't reach field capacity under rainfed conditions)

ΔSWC – change in soil water content

***Thus, ET=P*± ΔSWC**

The outcome of the assessments for Ntshiqo and Muden are discussed below.

Ntshiqo, Eastern Cape

Comparison of observed and simulated evapotranspiration (ET) in Ntshiqo sites show that AquaCrop performed well with respect to predicting ET (Figure 5.30). The simulated ET ranged from 458.5 mm to 487.4 mm across all sites. This range was not far off when compared to the observed ET, which ranged from 426 mm to 575 mm. the observed ET was generally higher than simulated ET for Madosini, Beya, and Mjali across the treatment and control. The observed ET results show that RWH&C had a remarkably higher ET compared to the control across all site, whereas the simulated ET results showed no remarkable differences (Figure 5.30). Comparing observed and simulated water productivity (WP) showed that there were remarkable differences between the observed and simulated data. The results show that yield is responsible for the differences observed between the observed and simulated water productivity. The model predicted yields 50% higher than what was observed in the demonstrations, giving the modelled yields higher water productivity. The simulated WP ranged from 1.56 to 1.81 kg.m^{-3} whereas the observed ranged from 0.29 to 0.87 kg.m^{-3} (Figure 5.31). AquaCrop consistently predicted that RWH&C has higher WP compared to the control in all sites. The observed results however, do not show this pattern and only Madosini and Mjali results are in agreement with the model. For Quvile and Sokhombela, the control shows superior WP when compared to RWH&C (Figure 5.31).

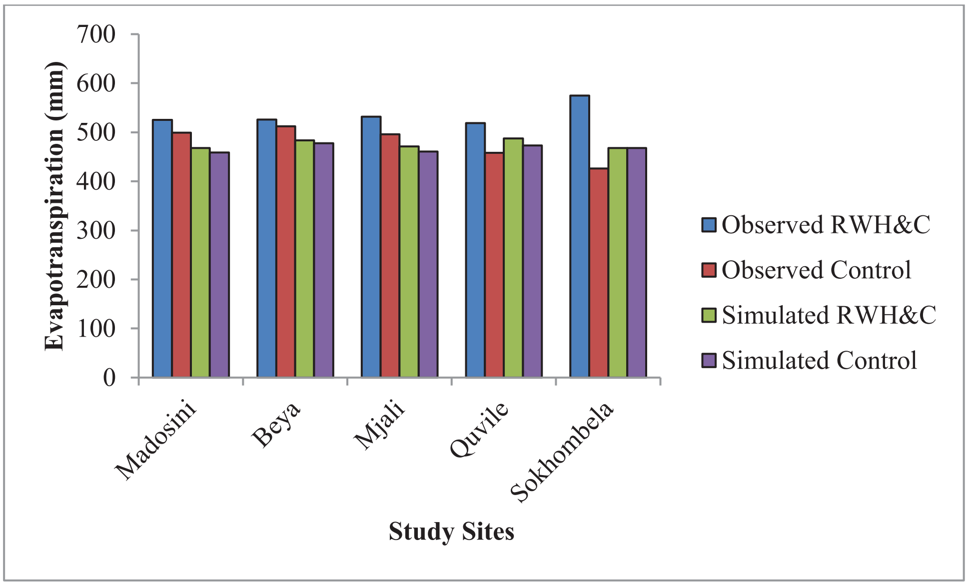


Figure 5.30: Observed and simulated Evapotranspiration for the 2014/2015 growing season in Ntshiqo, Eastern Cape

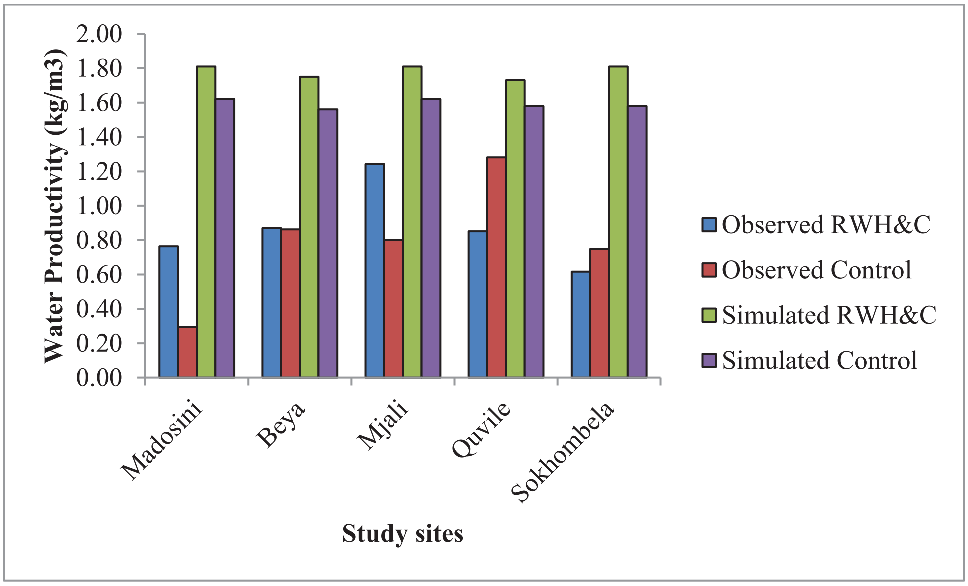


Figure 5.31: Observed and simulated Water Productivity for the 2014/2015 growing season in Ntshiqo, Eastern Cape

Muden – Mxheleni

The observed evapotranspiration at Mxheleni show that there were no remarkable differences between RWH&C and control regarding ET (RWH&C = 220.6; Control = 235.7). The simulated ET for RWH&C was superior to that of the control but this was not the case for the observed ET (Figure 5.32).

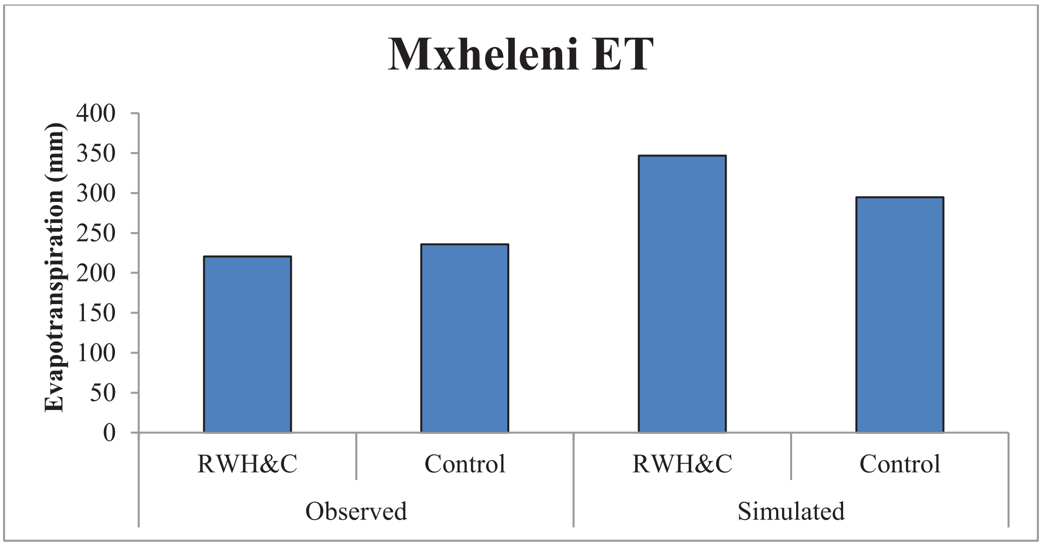


Figure 5.32: Observed and simulated evapotranspiration (ET) at Mxheleni in 2015/2016 growing season

In overall, the observed ET showed lower values compared to simulated ET, the model predictions for RWH&C and control were 347 mm and 294.7 mm respectively and observed ET were 220.6 and 235.7 mm respectively.

The WP results at Mxheleni revealed that RWH&C maintained superior WP across the observed and simulated results. The observed WP was 0.89 $kg.m^{-3}$ for the control and 1.16 $kg.m^{-3}$ for the treatment; where the simulated WP for RWH&C was 1.54 $kg.m^{-3}$ and 1.44 $kg.m^{-3}$ for the control. AquaCrop predictions with respect to WP at Mxheleni were not out of range when compared with observed data (Figure 5.33).

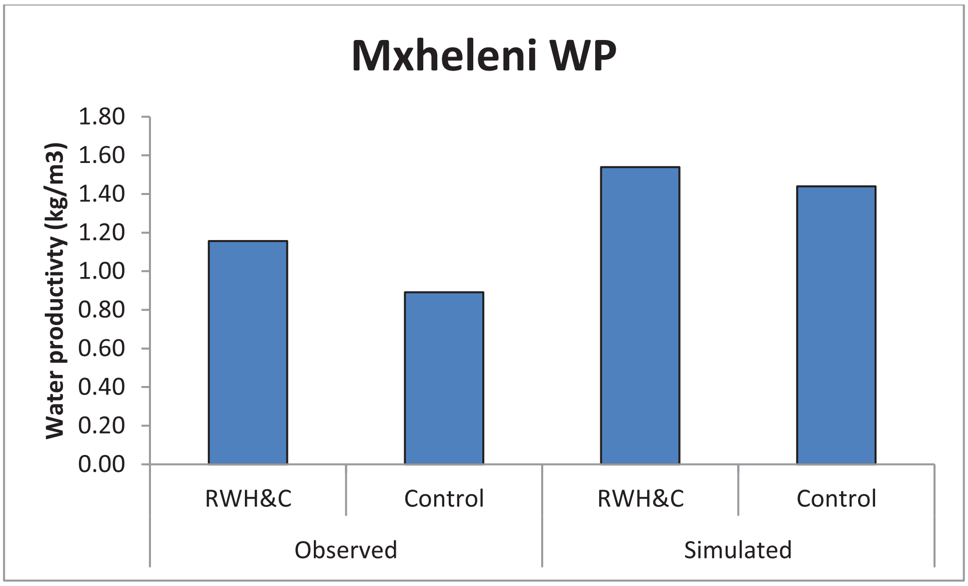
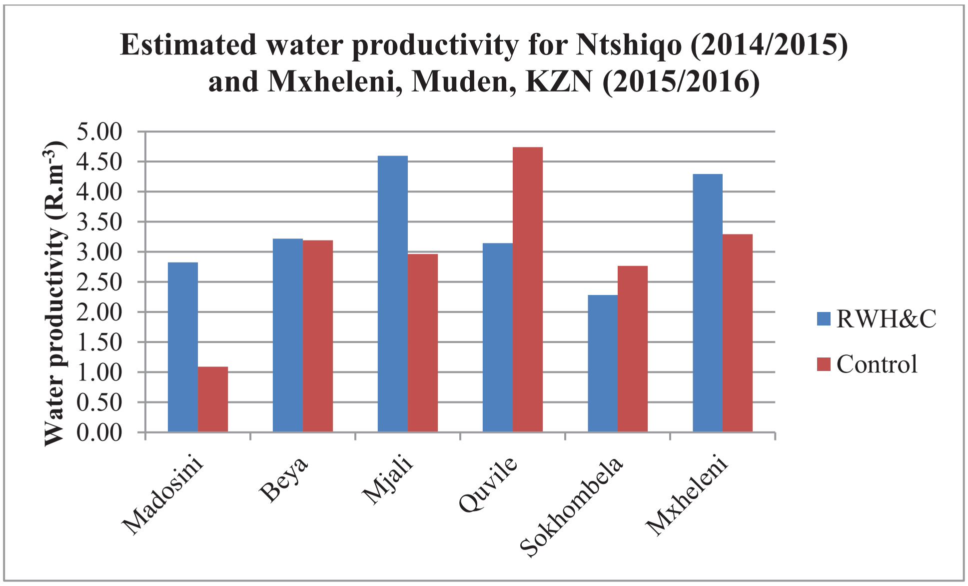


Figure 5.33: Observed and simulated water productivity in 2015/2016 growing season at Mxheleni, KwaZulu-Natal

5.7 Crop water productivity values at the research sites

Based on the observed water productivity calculations derived from 5.5, the rand value of water productivity was calculated based on the June 2016 average yellow maize prices, which was R3 700 per ton (http://www.sagis.org.za/safex_historic.html). The results are presented in Figure 5.34.



.

Figure 5.34: Estimated water productivity for Ntshiqo (2014/2015) and Muden (2015/2016)

Table 5.24: Summary of water productivity for the research sites in Eastern Cape (2014/2015) and KwaZulu-Natal (2015/2016)

	Observed				Simulated			
	RWH&C		Control		RWH&C		Control	
	$kg.m^{-3}$	$kg.m^{-3}$	$kg.m^{-3}$	$kg.m^{-3}$	$kg.m^{-3}$	$kg.m^{-3}$	$kg.m^{-3}$	$kg.m^{-3}$
Ntshiqo, Eastern Cape (2014/2015)								
Madosini	0.76	2.83	0.29	1.09	1.81	6.70	1.62	5.99
Beya	0.87	3.22	0.86	3.19	1.75	6.48	1.56	5.77
Mjali	1.24	4.60	0.80	2.97	1.81	6.70	1.62	5.99
Quvile	0.85	3.15	1.28	4.74	1.73	6.40	1.58	5.85
Sokhombela	0.62	2.28	0.75	2.77	1.81	6.70	1.58	5.85
Muden, KwaZulu-Natal (2015/2016)								
Mxheleni	1.16	4.29	0.89	3.29	1.54	5.70	1.44	5.33

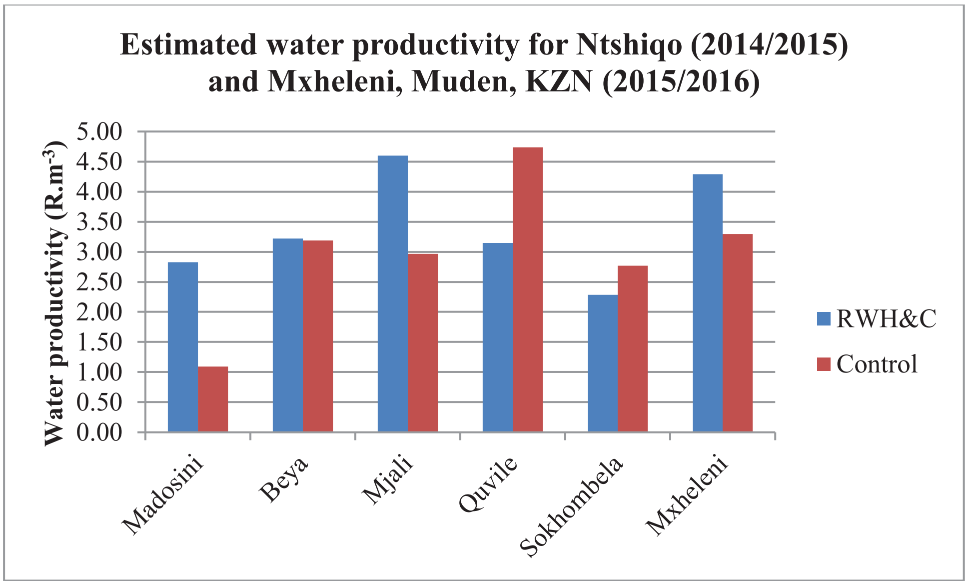


Figure 5.35: Rand value of water productivity

The highest value interestingly, came from a control site (R4.74 per m^3) for Mrs Quvile. As indicated earlier, this site was found to have wetter subsoil, particularly in the control areas, which accounts to some degree for the higher values observed for the control at this site. The Mjali RWH&C treatment had the next highest WP at R4.60 per m^3. The lowest water productivity was in Mrs Madosini's control at R1.09 per m^3.

5.8 Discussion of the findings from the crop research

The yield results suggest that RWH&C is one of the cropping systems that can be adopted to improve production in low yielding rainfed areas. Descheemaeker et al. (2013) stated that improving productivity of water in low yielding rainfed areas would result in multiple benefits for rural farmers. This was manifested especially at Muden (Mxheleni) where RWH&C improved yields and reduced soil erosion. Results of some of the sites indicated a decline in yield indicators in the RWH&C treatments. These observations were inconsistent with literature and expectations.

The results of 2013/2014 at Ntshiqo showed an interesting pattern with respect to harvest index. Harvest index is defined as a proportion of biomass allocated to grain and it is a measure of the plant's efficiency with respect to source sink balance (Wnuk et al., 2013). RWH&C showed lower grain yield and biomass compared to control, but the harvesting index was vice versa. This might be attributed to RWH&C improved the efficiency of the crop with respect to channelling assimilates from the source to the sink. This concept would however, need further research.

The crop failures observed at Fabeni were due to severe drought condition experienced during the time of the demonstrations. According to the Bioresource information Fabeni receives about 600 mm of rainfall per annum. Climatic data obtained from the Automatic Weather Station installed on site indicated that in 2014/15 and 2015/2016 about 428.9 and 323.6 mm of rainfall was received per annum respectively. During the critical stages of crop development, the average high temperatures were above 35°C, and rainfall received ranged between 53 to 78 mm. This means there was a very high evaporative demand and this posed stress to the crop and probably contributed to crop failure.

The AquaCrop model performed well with respect to yield and water productivity responses to RWH&C, however, the model tends to over-estimate the yields. Subsistence farmers are still faced with challenges of low crop productivity which contribute greatly to their status of household food security (Hensley, 2000). Because they are farming on marginal soils, with little on fertilizer, there is limited water for irrigation and poor management practices. Therefore it is highly unlikely that the yields predicted by the model would be obtained in most cases. Weeding was a problem at the demonstration sites, for example of one of the participant farmer performed only one weeding exercise in the growing season and weeds were observed to have a negative effect on his yield (Figure 5.36).Weeds contribute to the non-beneficial consumption of water. In particular, weeks compete strongly with crops in their early growth stages and hence proper weed control is important.

Figure 5.36: Mr Sokhombela's garden in Ntshiqo showing high infestation of weeds

The other possible explanation for why the model predicted such high yields would be that it predicts potential yields rather than actual on-farm yields. There are three types of yields i.e. water limited yield (Yw), locally attainable yield (Y_L) and actual on-farm yield (Tittonell and Giller 2013). Water limited yield is defined as maximum yield obtained under rainfed conditions when soil water capture and storage is optimal and nutrient constraints are not limiting (van Ittersum et al., 2013). Attainable yields are yields achievable at a local region given limited average nutrient and water resources (De Wit 1992). The actual yields (Ya) are defined as the average yields obtained by farmers in a particular region under dominant management practices. Two major yield gaps exist, namely the gap between Yw and Ya and yield gap between Y_L and Ya (Tittonell and Giller 2013). In the context of this study the model might be estimating the water limited yield as opposed to actual yield (Ya). According to FAO Stats, smallholder farmers in Sub-Saharan Africa produce about 1.51 $ton.ha^{-1}$ of maize which is in agreement with the baseline yields for Ntshiqo obtained in 2013/14 and 2014/15, which ranged from 1.2 to 1.6 ton/ha.

The observed soil water content (SWC) showed a lot of variations and no tangible trend was observed, although when one sums up the SWC observed on the runoff, above and below ridge, then the RWH&C generally showed higher SWC compared to the control. With respect to simulated SWC, the model did not show distinctions between the RWH&C and control. As explained on section 2.5.3, the field management file of AquaCrop was the main distinguishing field with regards to RWH&C and control. The RWH&C file had soil bunds for water storage in the field and hence reduced runoff, whereas the control file had no soil bunds and hence high chances of runoff losses. The model did not simulate the effect of soil bunds on SWC. Further work and better understanding of the model is required to answer this question.

The model did not predict crop failure in any the sites at Muden, while in reality this occurred for all three seasons at Fabeni and in one of the three seasons at Mxheleni. The model performance depends on the data fed to it, and the most sensitive data are the climatic data. The climatic data from Muden indicated rainfall events during the planting seasons, however, it did not take into account the fact that a very small percentage of this rainfall infiltrates the soil and become available to the crop. Muden is characterised by very shallow soils with poor drainage hence a lot of rainfall is lost through runoff. Usually after rainfall events, there are very strong winds which accelerate the rate of evapotranspiration. As a result of these factors, the model was not able to account for all these realities and it tended to overestimate yields.

5.9 Results of livestock water productivity research

Due to the devastating drought that occurred in Muden in 2014/2015 and 2015/2016 (See 5.1.2 and 5.2.2), the livestock research was discontinued and consequently, the focus in this section is on the research conducted at Ntshiqo.

5.9.1 Rangeland condition

The success of livestock production in an area is determined by the condition of the rangeland (Tau, 2005). Rangeland condition or rangeland health can be determined by species composition (Tainton, 1999). Factors that affect the condition are grazing capacity and stocking density (Tainton, 1981). Classification of grasses into their ecological status based on their reaction to different levels of grazing is important in determining the species composition and veld condition of rangelands (Van Oudsthoorn 2012). This aids in identifying rangeland management interventions. The ecological status of the grasses at the sites is provided in Table 5.25 (see Figure 3.1 for a map of the locations of the sampling sites), compared against the Benchmark for the area. It is clear that the grasslands at Ntshiqo are dominated by Increaser II species, which are species that increase in abundance under conditions of overgrazing.

Table 5.25: The percentage of the ecological status of grasses, for Sites 1-3 at Ntshiqo, Eastern Cape in 2014

Ecological status of grasses (%)	Site 1	Site 2	Site 3	BRG 8 Benchmark
Decreaser species	27.5	0	5	49
Increaser I species	12	2	6	25
Increaser II species	60.5	98	89	19
Increaser III species	0	0	0	7
Total	**100**	**100**	**100**	**100**

An assessment of the species composition of an area allows for the calculation of current grazing capacity, veld condition and stocking density which are important components for rangeland management (Tau, 2005; Mapako, 2011). Due to continuous overgrazing of this veld, the average current grazing capacity of the three sites has been reduced to 0.30 $AU.ha^{-1}$ from a potential 0.67 $AU.ha^{-1}$. Sites 1, 2 and 3 had a veld condition of 52.52%, 41.18% and 29.34% respectively, with an overall average veld condition of 38.94%. More detail regarding the veld condition and carrying capacity at Ntshiqo is summarised in Table 5.26.

The low grazing values of these species indicated a low potential of the land to support a large number of animals. This was verified by the following calculation of stocking density that the site can support:

Stocking Density = Total Grazing area x Average Current Grazing Capacity

= 1454 ha x 0.30 $AU.ha^{-1}$ = 436 Animal Units (AU)

Table 5.26: Comparison of the veld condition scores, potential grazing capacities and current grazing capacities for Sites 1-3 at Ntshiqo, Eastern Cape in 2014

Sites	Veld Condition (%)	Potential Grazing Capacity (AU ha^{-1})	Current Grazing Capacity (AU ha^{-1})
Site 1	52.52	0.67	0.32
Site 2	41.18	0.67	0.30
Site 3	29.34	0.67	0.28
Mean	41.01	0.67	0.30

An Animal Unit (AU) is defined as the forage requirement of livestock (Scarnecchia, 1985). The results of this study indicated that the stocking density for Ntshiqo (1 454 ha) that can be supported by veld in this condition was 436 AU. In Ntshiqo there were 5 846 animals (806 cattle, 4088 sheep, and 952 goats). The carrying capacity is generally based on the standard biomass (i.e. 450 kg) and forage requirement of one AU for commercial cattle (Meissner, 1982). For communal cattle, this value was adjusted to 0.75 Animal Unit Equivalent (AUE) (i.e. 375 kg) as they have lower forage requirements (Meissner, 1982). AUE is based on a percentage of the standard AU and takes into account physiological differences of livestock (Scarnecchia, 1985). Therefore the cattle population was comprised of 604.5 AU (806*0.75). The AUE for sheep, goats and horses were 0.20, 0.15 and 1.25 respectively. In Ntshiqo, the actual stocking density was 1 666 AU, which is just under four times the recommended stocking density.

The high stocking density at Ntshiqo has resulted in severe overgrazing. This has resulted in poor veld condition of the area. There were no resting or grazing initiatives, which indicated that appropriate management interventions were lacking (LWG, 2015).

5.9.2 Forage quantity and quality

The forage quantity and quality produced in the exclosures and continuously grazed areas, and the rotational resting experiments are presented below.

Exclosures and grazed areas

Forage quantity

Biomass production of the continuously grazed sites (representing the grazing regime practised by the livestock owners) was low at all sites with a maximum biomass of less than 2.1t.ha^{-1}. Following the first frost in June, mean biomass production decreased in all sites with no significant differences between the exclosures and grazed areas at the start of the experiment (0.26-1.56 t.ha^{-1}). These low values were expected due to the high utilisation of forage utilised by the livestock for winter grazing. However, continued exclusion of livestock in the exclosures resulted in significant increases in biomass. In Site 1, the peak mean biomass production in the exclosures (1.30 t.ha^{-1}) was reached in May 2015 with a corresponding value of 0.49 t.ha^{-1} in the grazed areas (Figure 5.37 - Figure 5.39). Peak mean biomass production for the grazed areas of 0.84 $t.ha^{-1}$ was produced in March 2015.

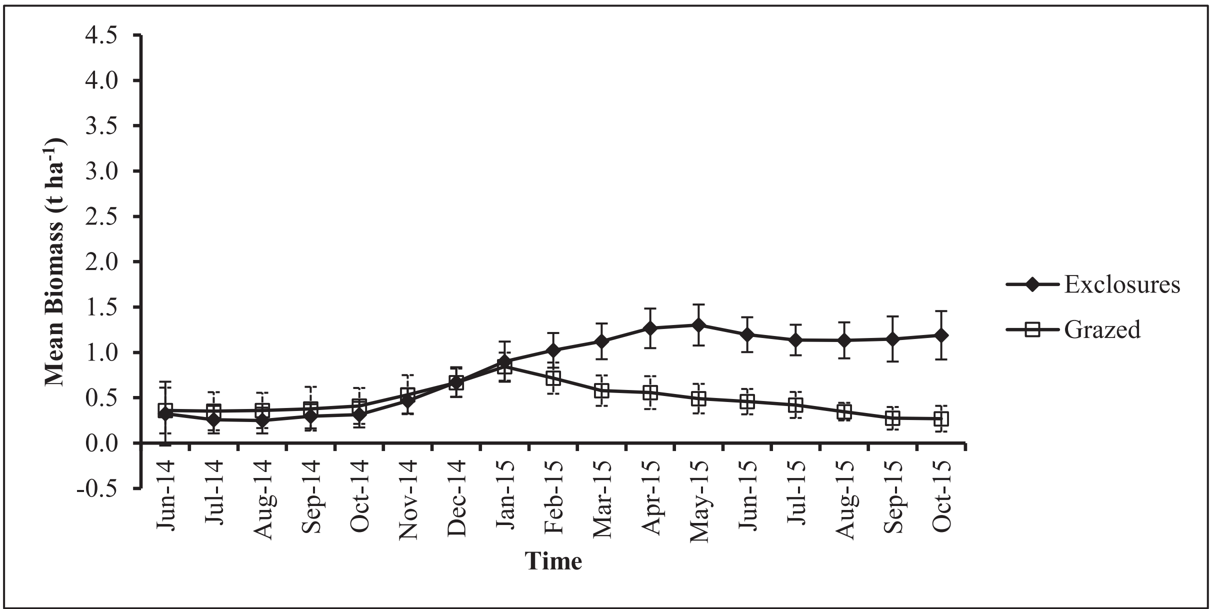


Figure 5.37: Site 1: Mean (± se) biomass for exclosures and grazed areas over time at Ntshiqo, Eastern Cape for 2014/15

At Site 2, the peak mean biomass production of the exclosures (3.97 $t.ha^{-1}$) was reached in May 2015 compared to 1.87 $t.ha^{-1}$ produced in March 2015 in the grazed areas (Figure 5.38). Peak mean biomass production for the grazed areas (2.08 $t.ha^{-1}$) was in March 2015.

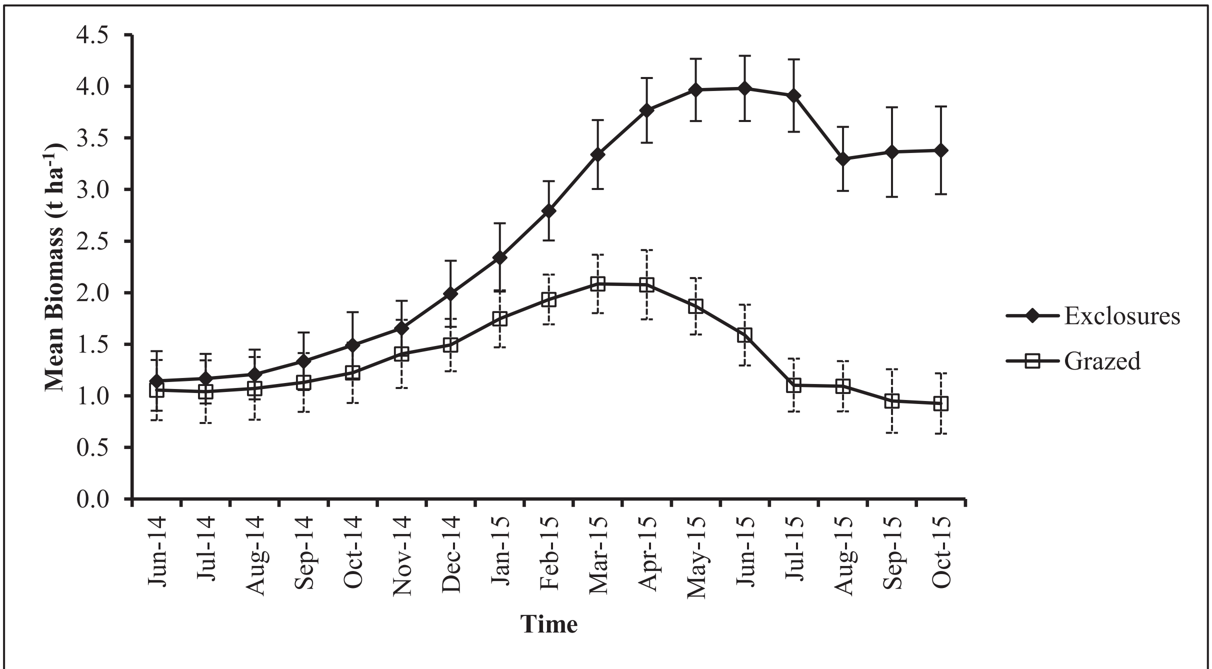


Figure 5.38: Site 2, mean (± se) biomass for exclosures and grazed areas over time

At Site 3, the peak mean biomass production in the exclosures (2.43 $t.ha^{-1}$) was reached in May 2015 compared to 1.29 $t.ha^{-1}$ in the grazed outside areas (Figure 5.39). Peak mean biomass production for the grazed areas of 1.46 $t.ha^{-1}$ was produced in April 2015.

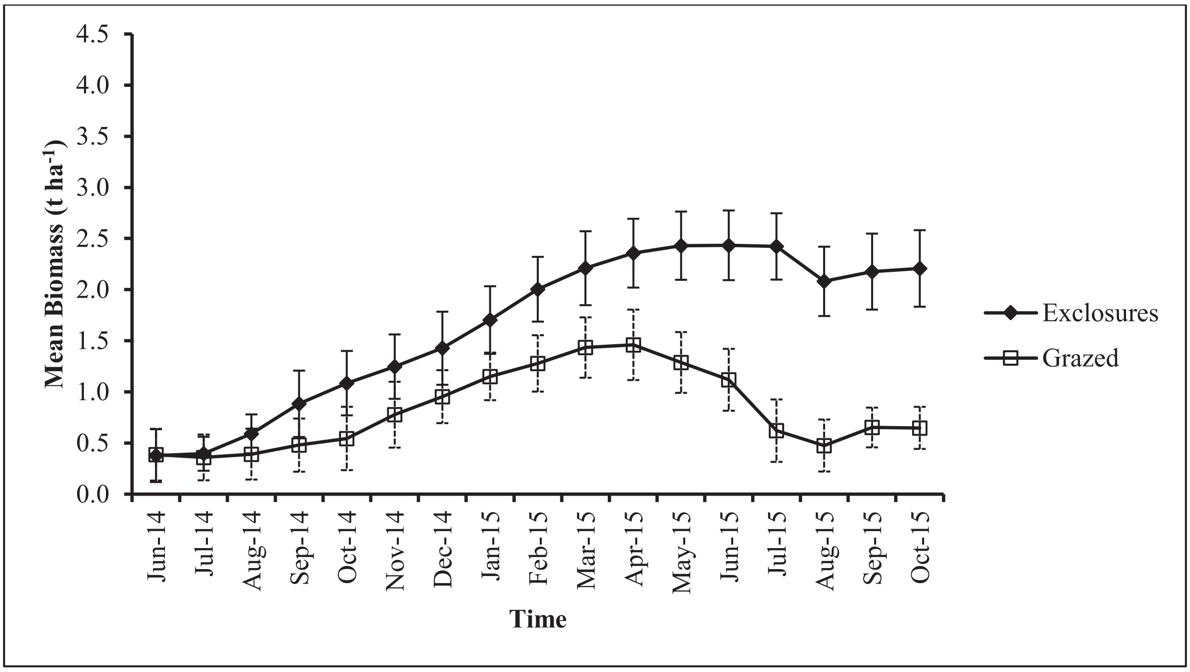


Figure 5.39: Site 3, mean (± se) biomass for exclosures and grazed areas over time (Ntshiqo, Eastern Cape)

The peak (May) and end (August) of the growing seasons were compared to obtain the range of biomass produced in the Ntshiqo rangeland. The mean biomass produced in the exclosures and grazed areas were 2.57 and 1.22 $t.ha^{-1}$ respectively (Table 5.27). The exclosures during the peak growing season produced significantly more ($t = 4.34$, $p<0.001$, $df = 8$) biomass when compared to continuously grazed areas (Table 4.4). This depicted a four-fold increase in biomass production in the exclosures during the peak growing season, compared to the initial values at the start of the experiment. The mean difference in yield was 1.35 ± 0.311 $t.ha^{-1}$, approximately twice as much as the continuously grazed areas (Table 5.27). The mean biomass produced during the end of the growing season in the exclosures and grazed areas was 2.17 and 0.65 $t.ha^{-1}$ respectively (Table 5.32). The exclosures during the end of the growing season produced significantly higher ($t=5.56$, $p< 0.001$, $df= 8$) biomass compared to the grazed areas (Table 5.32). The mean difference in yield was 1.52 ± 0.273 $t.ha^{-1}$, over three times as much as the continuously grazed areas. The difference in biomass between adjacent continuously grazed and protected areas is highlighted in Figure 5.40. Site 2 produced much higher biomass compared to the other sites, due to the high composition of Increaser II (98%) species (Table 5.25). This resulted in reduced grazing of biomass thereby promoting the growth of mature and moribund material. This is unacceptable to livestock, hence higher biomass production. There was a consistent directional change between the 9 replicates of paired samples, with the exclosures having a higher biomass than the grazed areas in both the peak and end of the growing season (Figure 5.40).

Table 5.27: Mean biomass ($t.ha^{-1}$) produced at the peak (May) and end of the growing season (August), in the exclosures and grazed areas for Sites 1-3 at Ntshiqo

	Site	Mean Grazed Biomass ($t\ ha^{-1}$)	Mean Exclosures Biomass ($t\ ha^{-1}$)	Mean difference ($t\ ha^{-1}$)	sd	se	t-value	p-value
Peak of Growing Season (May)	Site 1	0.49	1.30	0.81	0.227	0.131		
	Site 2	1.87	3.97	2.10	1.445	0.834		
	Site 3	1.29	2.43	1.14	0.052	0.030		
	Overall	1.22	2.57	1.35	0.933	0.311	4.34	0.001
End of Growing Season (August)	Site 1	0.35	1.13	0.79	0.291	0.168		
	Site 2	1.09	3.30	2.20	0.983	0.568		
	Site 3	0.52	2.08	1.56	0.336	0.194		
	Overall	0.65	2.17	1.52	0.818	0.273	5.56	p<0.0001

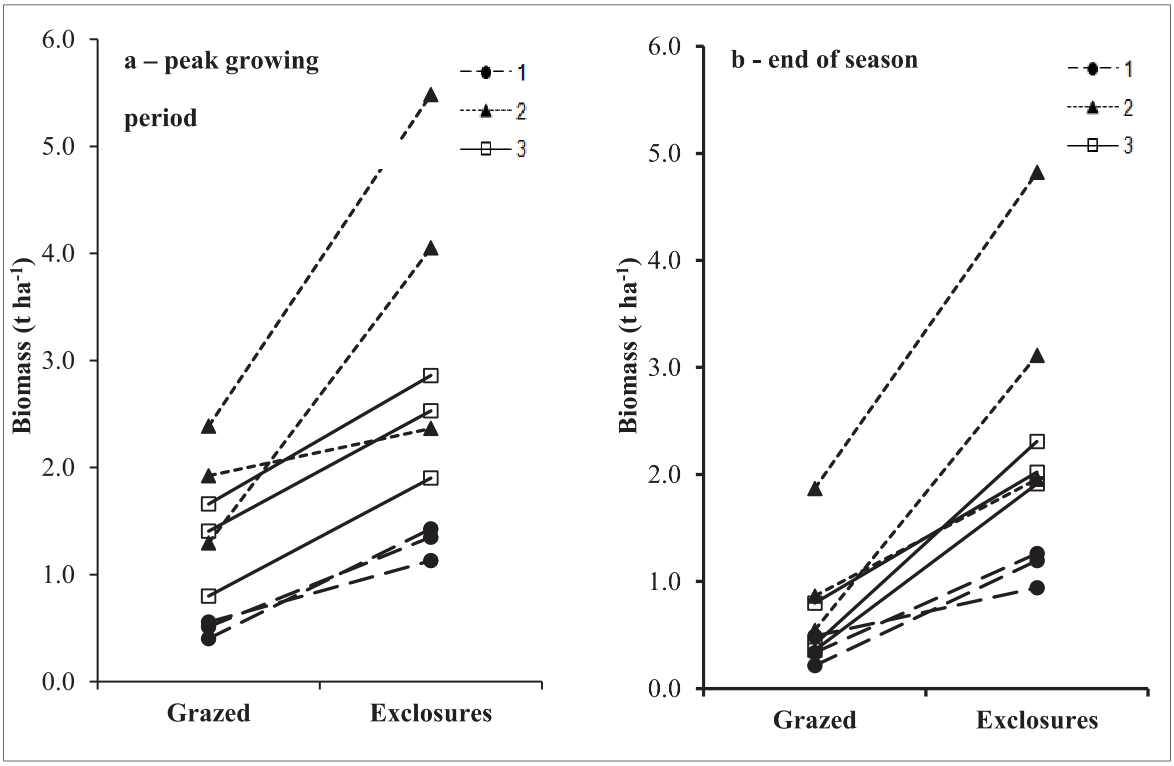


Figure 5.40: Mean biomass comparisons between 9 replicates of paired samples of exclosures and grazed areas in (a) peak of growing season (May), and (b) end of growing season (August) (1 = Site 1, 2 = Site 2, 3= Site 3)

Local community members in Ntshiqo were satisfied with the results, realising the positive impacts of resting on biomass production (LWG, 2015). While this long term rest (17 months) had the potential to have a positive effect on livestock production, determining the quality of this biomass was critical. Sourveld is characterised by poor digestibility, intake and forage quality during the winter months, negatively affecting animal productivity (O'Reagain and Mentis, 1988; Danckwerts, 1989; De Bruyn and Koster, 2000; Kirkman and De Faccio Carvalho, 2003).

Forage quality

The amount of fibre in the grass is an indication of its quality with high fibre reducing the digestibility and intake of forage (Beauchemin, 1996; Ball et al., 2001). The digestibility and intake of forage are important components affecting the diet of livestock.

During summer (February) the mean Acid Detergent Fibre (ADF) values across all the exclosures and grazed areas was 47.85 and 47.44%, respectively (Table 5.28). These are high values, indicating mature forage with low digestibility and high fibre content (De Bruyn and Koster, 2000; Newman et al., 2006; Mapako, 2011). There was no significant difference (t= 0.42, p= 0.685, df= 8) in ADF values between the exclosures and grazed areas (Table 5.29). During winter (June) the mean ADF values in the exclosures and grazed areas were 49.40 and 48.22% respectively. No significant difference (t= 0.80, p= 0.447, df= 8) was evident between ADF values in exclosures and grazed areas in winter (Table 5.28). The mean difference in ADF values is 1.18 ± 1.477 %. In spring (October) the mean ADF values in the exclosures and grazed areas were 46.10 and 45.07% respectively. No significant difference (t= 0.49, p= 0.639, df= 8) was evident, with a mean difference in ADF values between the treatments of 1.03 ± 2.111 %.

Table 5.28: Summary table comparing the mean ADF (%) values produced in summer (February), winter (June) and spring (October) in the exclosures and grazed areas for Sites 1-3 at Ntshiqo, Eastern Cape

	Site	Mean ADF Grazed (%)	Mean ADF Exclosures (%)	Mean difference (%)	sd	se	t-value	p-value
Summer (February)	Site 1	48.76	47.10	-1.66	1.243	0.718		
	Site 2	47.90	48.11	0.21	2.985	1.723		
	Site 3	45.66	48.33	2.68	3.058	1.765		
	Overall	47.44	47.85	0.41	2.915	0.972	0.42	0.685
Winter (June)	Site 1	48.77	46.70	-2.06	0.734	0.424		
	Site 2	51.17	50.32	-0.85	2.931	1.692		
	Site 3	44.71	51.17	6.46	2.381	1.375		
	Overall	48.22	49.40	1.18	4.431	1.477	0.80	0.447
Spring (October)	Site 1	46.18	51.24	5.06	5.479	3.163		
	Site 2	46.95	43.93	-3.03	1.211	0.699		
	Site 3	42.08	43.13	1.05	8.937	5.160		
	Overall	45.07	46.10	1.03	6.333	2.111	0.49	0.639

The mean Neutral Detergent Fibre (NDF) values across all the exclosures and grazed areas during summer, was 78.10 and 80.80% respectively (Table 5.29). These are high NDF values which depicted mature forage, with a high fibre content and low intake (Beauchemin, 1996; Ball et al., 2001). There was no significant difference (t= 2.07, p= 0.072, df= 8) between NDF values in exclosures and grazed areas. During winter the mean NDF values in the exclosures and grazed areas were 80.71 and 82.03%. There was no significant difference (t= 1.20, p= 0.266, df= 8) between NDF values in the treatments. The mean difference in NDF values was -1.32 ± 1.102 %. In spring (October) the mean NDF values in the exclosures and grazed areas were 83.16 and 84.01% respectively. No significant difference (t= 0.54, p= 0.601, df= 8) was evident, with a mean difference in NDF values between the treatments of -0.85 ± 1.563% (Table 5.29).

Table 5.29: Summary table comparing the mean NDF (%) values produced in summer (February), winter (June) and spring (October) in the exclosures and grazed areas for Sites 1-3 at Ntshiqo, Eastern Cape

	Site	Mean NDF Grazed (%)	Mean NDF Exclosures (%)	Mean difference (%)	sd	se	t-value	p-value
Summer (February)	Site 1	79.97	74.03	-5.94	4.669	2.696		
	Site 2	80.83	78.71	-2.12	3.031	1.750		
	Site 3	81.60	81.56	-0.03	1.736	1.002		
	Overall	80.80	78.10	-2.70	3.904	1.301	2.07	0.072
Winter (June)	Site 1	79.49	76.61	-2.89	3.696	2.134		
	Site 2	84.29	83.13	-1.16	2.306	1.331		
	Site 3	82.31	82.40	0.09	4.250	2.454		
	Overall	82.03	80.71	-1.32	3.307	1.102	1.20	0.266
Spring (October)	Site 1	86.29	82.52	-3.78	3.568	2.060		
	Site 2	83.27	87.27	4.00	4.198	2.424		
	Site 3	82.48	79.70	-2.78	1.978	1.142		
	Overall	84.01	83.16	-0.85	4.690	1.563	0.54	0.601

Crude protein (CP) is a critical nutrient for livestock health (Van Niekerk and Jacobs, 1985). The crude protein content in forage is vital in determining livestock production (Sprinkle, 2001). The mean CP values in the exclosures and grazed areas during summer were 5.04 and 5.57% respectively (Table 5.30). These depicted low CP values (Newman, 2006; Mapako, 2011; Munyai, 2012). There was no significant difference (t= 2.26, p= 0.054, df= 8) between CP values in exclosures and grazed areas. During winter the mean CP values in the exclosures and grazed areas were 2.52 and 2.90% respectively, indicating that the quality of the forage was critically low. No significant difference (t= 1.39, p= 0.202, df= 8) was found between CP values in the treatments. The mean difference in CP values was -0.38 ± 0.273 %. In spring (October) the mean CP values in the exclosures and grazed areas were 4.55 and 4.50% respectively (Table 5.30). No significant difference (t= 0.14, p= 0.891, df= 8) was evident, with a mean difference in CP values between the treatments of 0.05 ± 0.327%. It is evident that protein supplementation is required in Ntshiqo to improve animal productivity especially during winter (Table 5.30).

Phosphorus (P) is a vital limiting plant nutrient which impacts on animal performance (Van Niekerk and Jacobs, 1985; Miller and Gardiner, 1998).

During summer, the exclosures and grazed areas had mean P values of 0.06 and 0.07% respectively (Table 5.31). This depicted significantly low values (Mapako, 2011). According to the NRC (1984), a lactating cow requires 0.27% P in a pasture. Therefore these values indicated a P deficiency (De Brouwer et al., 2000). There was no significant difference (t= 2.38, p= 0.051, df= 8) between P values in exclosures and grazed areas. The mean P values in the exclosures and grazed areas during winter were 0.06 and 0.04% respectively. There was no significant difference (t= 0.68, p= 0.515, df= 8) between values in exclosures and grazed areas.

The mean difference in P values was 0.02 ± 0.030 %. Exclosure 1 at Site 2 had a high P value for unknown reasons. In spring (October) the mean P values in the exclosures and grazed areas were 0.06 and 0.06% respectively. No significant difference (t= 1.00, p= 0.348, df= 8) was evident, with a mean difference in P values between the treatments of 0.01 ± 0.007% (Table 5.31).

Table 5.30: Mean CP (%) values produced in summer (February), winter (June) and spring (October) in the exclosures and grazed areas for Sites 1-3 in Ntshiqo, E. Cape

	Site	Mean CP Grazed (%)	Mean CP Exclosures (%)	Mean difference (%)	sd	se	t-value	p-value
Summer (February)	Site 1	5.30	5.13	-0.18	0.124	0.072		
	Site 2	5.80	4.72	-1.08	0.374	0.216		
	Site 3	5.62	5.27	-0.35	1.082	0.625		
	Overall	5.57	5.04	-0.53	0.709	0.236	2.26	0.054
Winter (June)	Site 1	2.63	2.41	-0.22	0.086	0.049		
	Site 2	2.65	2.81	0.17	0.473	0.273		
	Site 3	3.42	2.33	-1.08	1.110	0.641		
	Overall	2.90	2.52	-0.38	0.819	0.273	1.39	0.202
Spring (October)	Site 1	4.39	4.54	0.15	1.500	0.866		
	Site 2	4.38	4.48	0.10	1.038	0.599		
	Site 3	4.74	4.63	-0.11	0.680	0.393		
	Overall	4.50	4.55	0.05	0.981	0.327	0.14	0.891

Table 5.31: The mean P (%) values produced in summer (February), winter (June) and spring (October) in the exclosures and grazed areas for Sites 1-3

	Site	Mean P Grazed (%)	Mean P Exclosures (%)	Mean difference (%)	sd	se	t-value	p-value
Summer (February)	Site 1	0.08	0.06	-0.01	0.013	0.007		
	Site 2	0.07	0.05	-0.02	0.010	0.006		
	Site 3	0.07	0.07	0.00	0.011	0.006		
	Overall	0.07	0.06	-0.01	0.012	0.004	2.38	0.051
Winter (June)	Site 1	0.04	0.04	-0.01	0.012	0.007		
	Site 2	0.04	0.12	0.08	0.149	0.086		
	Site 3	0.05	0.04	-0.02	0.015	0.009		
	Overall	0.04	0.06	0.02	0.089	0.030	0.68	0.515
Spring (October)	Site 1	0.05	0.07	0.02	0.035	0.020		
	Site 2	0.06	0.05	0.00	0.008	0.004		
	Site 3	0.06	0.07	0.00	0.008	0.005		
	Overall	0.06	0.06	0.01	0.021	0.007	1.00	0.348

No additional information was provided by the Ntshiqo community members regarding the quality of the veld, due to the complex nature of such feed analyses (LWG, 2015). The resting of veld is considered a vital intervention for good rangeland management in all types of veld (O'Reagain, 1994; Tainton and Danckwerts, 1999; Descheemaeker et al., 2006). The impact of a short and full summer rest on forage quantity and quality was assessed.

Rotational resting

Forage quantity

It was evident that resting for a full summer period (October 2014 – June 2015) produced significantly more biomass compared to a short summer rest (October 2014 – January 2015) (Figure 5.41). The mean biomass in the short summer rested area increased from 0.41 to 0.84 $t.ha^{-1}$, indicating a two-fold increase in biomass production. Once the short summer rested area was opened for grazing in January the biomass decreased to the pre-rest levels. The increase in mean biomass in the full summer rested area from 0.40 to 1.97 $t.ha^{-1}$ indicated that resting the grass for the full growing season resulted in a five-fold increase in biomass production.

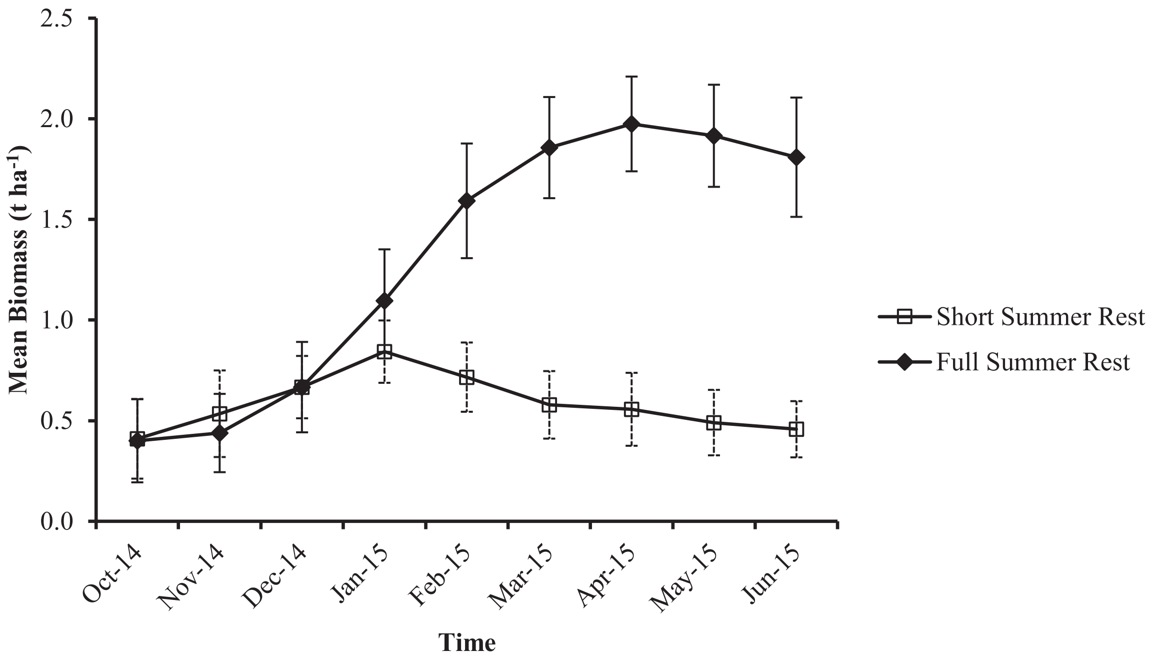


Figure 5.41: Mean (± se) biomass in the rotational resting treatment for a short and full summer rest

The mean biomass values for a short (October 2014 - January 2015) and full (Oct 2014 - June 2015) summer rest were 0.84 and 1.81 $t.ha^{-1}$ respectively (Table 5.32). A full summer rest produced significantly more biomass ($t= 4.37$, $p= 0.001$, $df=2$) than the short summer rest. The mean difference in yield was 0.97 ± 0.222 $t\ ha^{-1}$, which indicated that the full summer rest produced over twice as much biomass than the short summer rest. Again, the community members revealed a positive attitude towards the rotational resting experiments and realised the potential of resting on biomass production (LWG, 2015).

Table 5.32: Biomass (t ha^{-1}) produced in a short and full summer rotational resting experiment at Ntshiqo, Eastern Cape

	Mean Biomass (t ha^{-1})	Difference in Biomass (t ha^{-1})	Standard error for the difference between means (s.e.d.m)	sd	se	t-value	p-value
Short Summer Rest	0.84	0.97	0.222	0.101	0.059	4.37	0.001
Full Summer Rest	1.81			0.370	0.214		

Forage quality

There was a significant difference (t= 7.94, p= 0.004) between ADF values after a full summer rest compared to a short summer rest (Table 5.33). The mean difference in ADF values was 4.02 ± 0.506 % (Table 5.33). There was no significant difference (t= 0.09, p= 0.934, df= 2) between NDF values after a full summer rest compared to a short summer rest (Table 5.33). There was no significant difference (t= 2.11, p= 0.126, df= 2) between CP values after a full summer rest compared to a short summer rest (Table 5.33). No significant difference (t= 1.00, p= 0.423, df= 2) was found between P in a full summer rest compared to a short summer rest (Table 5.33).

Table 5.33: The mean ADF, NDF, CP and P (%) values in a short and full summer rotational resting experiment at Ntshiqo, Eastern Cape

	Mean (%)	Mean difference (%)	Standard error for the difference between means (s.e.d.m)	sd	se	t-value	p-value
ADF Short Summer Rest	48.77	4.02	0.506	0.759	0.438	7.94	0.004
ADF Full Summer Rest	52.79			0.439	0.253		
NDF Short Summer Rest	79.50	0.25	2.860	4.016	2.319	0.09	0.934
NDF Full Summer Rest	79.75			2.899	1.674		
CP Short Summer Rest	2.63	-0.29	0.254	0.093	0.054	2.11	0.126
CP Full Summer Rest	2.34			0.429	0.248		
P Short Summer Rest	0.04	0.00	0.003	0.006	0.003	1.00	0.423
P Full Summer Rest	0.04			0.000	0.000		

Nutrient deficiencies negatively affect animal health, condition and productivity (De Brouwer et al., 2000). CP was critically low, especially during winter. To address this problem an experiment was initiated to determine the effect of protein licks on the body condition of sheep.

5.9.3 Estimating LWP for the 2014/2015 season

This section discusses the estimated LWP of livestock in Ntshiqo for the 2014/2015 season.

Water consumption

Initially estimates of ET of grasslands from the literature were considered. Snyman (1988) states that ET is variable and ranges between 5.3 and 7.2 mm per day. More recently, Snyman (1999) found that grassland productivity ranged from 1.99 $kg.ha^{-1}.mm^{-1}$ (0.199 $kg.ha^{-1}.m^{-3}$) for rangeland in good condition, 1.38 $kg.ha^{-1}.mm^{-1}$ (0.138 $kg.ha^{-1}.m^{-3}$) in fair condition and 0.5 $kg.ha^{-1}.mm^{-1}$ (0.05 $kg.ha^{-1}.m^{-3}$) for rangeland in poor condition. The veld condition analysis suggests that most of the grasslands at Ntshiqo are in fair to poor condition (Table 5.26). Taking the assumption that the grassland in Ntshiqo was in poor condition, a productivity of 0.5 $kg.ha^{-1}.mm^{-1}$ (0.05 $kg.ha^{-1}.m^{-3}$) was applied.

To determine ET for the grassland, the mean standing biomass production from the exclosures for 2014/2015 season was used. The mean value of biomass production was 2.57 $t.ha^{-1}$ (Table 5.27). Applying the growth rates provided by Snyman (1998), an ET of 1 285 $mm.ha^{-1}$ is obtained (0.5 $kg.ha^{-1}mm^{-1}$ multiplied by 2.57 $t.ha^{-1}$). ET_0 from the weather station data for July 2014 to June 2015 was 1 105 mm, suggesting that this estimation is approximately correct. It is therefore assumed that water use of the grassland is 1 285 $mm.ha^{-1}$ (12 850 $m^3.ha^{-1}$)

Information on water use for the production of stover, which is grazed by livestock in winter, is derived from water productivity information presented in Table 5.22. The values for the control sites were used based on the assumption that most farmers in the area are making use of current practice rather than RWH&C. Based on this, the water use for biomass production (stover) for the homestead gardens is estimated to be 4 503 $m^3.ha^{-1}$ (Table 5.34).

Table 5.34: Water use for biomass production from homestead gardens at Ntshiqo

	Observed WP ($kg.m^{-3}$)	Harvest Index (%)	Biomass yield ($kg.ha^{-1}$)	Water use for biomass ($m^3.ha^{-1}$)
Madosini	0.29	16%	9 030	5 072
Beya	0.86	29%	15 300	5 131
Mjali	0.8	22%	17 920	4 975
Quvile	1.28	28%	5 830	1 275
Sokhombela	0.75	72%	6 350	6 063
Mean	**0.80**	**33%**	**10 886**	**4 503**

The water use of cropping fields is assumed to be the same as that of the homestead gardens.

To estimate the areas available for grazing, three elements were considered: the grazing area, grazing available within the homestead area and the area of the cropping fields (see Figure 3.1 for a map of the grazing, cropping fields and homestead areas). For the grazing area, it was determined from a mapping exercise that the grazing area is 1 200 ha. In calculating the grazing and stover available within the homestead area, it was assumed that patches of grazing available within the homestead area, were 20% of the 465 ha where homesteads occur (93 ha). It is further assumed that homestead gardens make up an additional 20% of the homestead area. The area of the cropping fields is 122 ha. From interviews with farmers, it is known that 54 ha of the cropping fields were planted, with the balance being fallow. Consequently, the water use of grasslands in poor condition will be applied to this area.

The calculations to estimate total water use for the areas grazed in Ntshiqo by livestock are provided in Table 5.35, which estimates the total water use for fodder production to be 18 150 791 m^3.

Table 5.35: Estimation of water use for fodder production by livestock

Description	**Area (ha)**	**Water use ($m^{-3}.ha^{-1}$)**	**Water use (m^3)**
Grazing area	1 200	12 850	15 420 000
20% of homestead area for grazing	93	12 850	1 195 050
20% of homestead area for stover	93	4 503	418 779
Area of fields used for crop production	54	4 503	243 162
Area of fields fallow	68	12 850	873 800
Total water use for livestock			**18 150 791**

Haileslassie et al. (2009) note that there are two approaches to determining feed consumed. One option assumes a surplus of feed. The second assumes that all available feed is used by livestock. Given the high stocking rates at Ntshiqo (see 5.8.1), it likely that all available feed is consumed and therefore biomass production is not required, only the water use of the areas that are grazed by livestock.

In terms of water used for drinking, it is assumed that cattle require 50 L water per day and sheep require 5 L water per day (Peden, Undated). From the mapping exercise, it is known that water is readily available for livestock and thus this is not a limiting factor. Assuming the total herd of cattle (808 animals) and the total herd of sheep (4 088 animals) drink their full requirement, a total of 20 m^3 is consumed as drinking water – negligible compared with the water use for fodder production (Table 5.36).

Table 5.36: Estimation of water drunk by livestock at Ntshiqo, Eastern Cape

Description	Number of animals	Daily Intake (L)	Annual intake (L)	Annual Intake (m^3)
Cattle	808	50	18 250	18.25
Sheep	4088	5	1 825	1.825
Total				20.075

Benefits from livestock

Haileslassie et al. (2009) list the major beneficial outputs from livestock as meat, milk, hides, manure and draught power. To determine the beneficial outputs for Ntshiqo, the following were considered:

- **Livestock sales (cattle and sheep)** - few sales or slaughter of livestock were reported by farmers participating in the survey and as a result, it was decided to focus on the live value of weaned calves and lambs produced during the 2014/2015 season. Based on discussions with farmers in Ntshiqo, the value of live calves and milk, in the case of cattle, and the value of live weaned lambs were derived. Only cows and ewes of breeding age were considered for this calculation.

- **Milk (cattle)** – a conservative estimate of 5 L per lactating cow per day is assumed, of which half is allocated for milk to be sold and the balance used for feeding calves. With 180 days lactation, 500 L of milk is assumed to be produced for sale at a price of R3.60 per litre. Only cows of breeding age were considered in this calculation.

- **Manure (cattle and sheep)** – livestock are kraaled at night for approximately 12 hours. Estimates of manure production by cattle are 2.3 $kg.day^{-1}$ and 0.28 $kg.day^{-1}$ for sheep (Haileslassie et al., 2009). Assuming half of the manure is eliminated in the kraals at night and available as fertiliser, 1.15 and 0.14 kg of manure is produced by cattle and sheep respectively per day. All livestock were included in this calculation. Abegaza et al., (2009) estimate the amount of N, P and K of livestock manure to be 1.5 $g.kg^{-1}$, 0.6 $g.kg^{-1}$ and 1.9 $g.kg^{-1}$ respectively. Furthermore, Abegaza et al., (2009) place the value of N, P and K at R12.74, R32.90 and R8.82 per kg respectively[4].

- **Wool (sheep)** - the value of wool derived per sheep was obtained from reports from four farmers who had sheared sheep. An average value of the clip per sheep of R27 was obtained. It was assumed that all sheep that are weaned will be clipped.

The value of draught power was excluded as this is no longer practiced in Ntshiqo. Similarly, no labour costs have been allocated in this valuation.

[4] Exchange rate of ZAR14 = USD1 is assumed.

The livestock surveys conducted as part of this research provide a good indication of the general herd / flock structure (see Table 5.6 to Table 5.11). Information provided by the livestock control officer puts the total number of livestock at 806 cattle and 4 088 sheep. The herd structure ratios derived from the livestock surveys were applied to the total number of cattle and sheep in Ntshiqo to derive a herd structure. This is presented in Table 5.37.

Table 5.37: Cattle and sheep numbers and herd structure at Ntshiqo, Eastern Cape in 2014/15

Type	Ratio	Number in communal herd	Type	Ratio	Number in communal flock
Cows	44%	353	**Ewes**	38%	1563
Heifers	16%	126	**Ewe Lambs**	16%	671
Bulls	3%	25	**Rams**	2%	79
Oxen	6%	50	**Wethers**	15%	596
Weaned	13%	101	**Weaned**	16%	658
Calves	19%	151	**Lambs**	13%	521
Total	100%	806	**Total**	100%	4 088

The calculations to determine the beneficial outputs from livestock in Ntshiqo in the 2014/2015 season are provided in Table 5.38 and Table 5.39, based on the assumptions discussed above.

Table 5.38: Estimated value of products from cattle in Ntshiqo, Eastern Cape in 2014/15

Description	Number / value
Value of live weaned calves	
No of breeding cows in communal herd	353
Calf weaning percentage	0.51
Total calves per annum	180
Value of live weaned calf (R)	2 000.00
Total value of calves	*359 677.50*
Value of Milk	
Milk obtained per cow per lactation (estimate)	500.00
Total milk obtained	176 312.50
Value of milk produced (at R3.60 per litre)	*634 725.00*
Value of manure	
Value of N per kg manure (R)	0.19
Value of P per kg manure (R)	0.20
Value of K per kg manure(R)	0.17
Total value of nutrients per kg manure	0.56
Amount of manure (kg/cow/day)	2.30

Recoverable manure (kg/animal/day)	1.15
Recoverable manure (kg/animal/annum)	419.75
Total number of cattle	*806.00*
Total value of manure (R)	*188 132.15*
Total value from cattle (R)	***1 182 534.65***

Table 5.39: Estimated value of products from sheep in Ntshiqo

Value of live weaned lambs (Rand)	**Number / value**
Lamb weaning %	0.73
Total lambs per annum	1 631
Value of live weaned lambs (R)	500
Total value of lambs (R)	*815 349*
Value of wool	
Value of wool obtained per animal (R)	27
No of sheep at shearing age	3 567
Total value of wool (R)	*96 311*
Value of manure	
Value of N per kg manure (R)	0.19
Value of P per kg manure (R)	0.20
Value of K per kg manure (R)	0.17
Total value of nutrients manure (Rands per kg)	0.56
Amount of manure (kg per animal per day)	0.28
Recoverable manure (kg per animal per day)	0.14
Recoverable manure (kg per animal per annum)	51.10
Total number of sheep	4 088.00
Total value of manure (R)	*116 163.33*
Total value from sheep (R)	***1 027 823***

Livestock water productivity

A total value from livestock in Ntshiqo of R2 210 357.30 was obtained, which translates to a water productivity of 0.12 $R.m^{-3}$ for all the areas grazed (grassland, homestead gardens and fields) as is shown in Table 5.40.

Table 5.40: Water productivity of livestock in Ntshiqo, Eastern Cape

Total value of livestock products (R)	**2 210 357.30**
Total ET (m^3)	18 150 811.08
Water productivity ($R.m^{-3}$)	0.12

Haileslassie et al. (2009), in a study in the Nile basin, found a water productivity of USD 0.3 – 0.6 per m^3 (equivalent to R4.20 – R8.40 per m^3)[5], which suggests that LWP for livestock in Ntshiqo is extremely low. While some of the value of sales of livestock may be underestimated, particularly the sale of livestock (few farmers reported any livestock sales), the following are areas where LWP can be increased:

- Increase lambing and calving percentages through improved grazing management, better healthcare and supplementary feeding.
- Improve the value of the wool produced – commercial sheep farmers derive an income of between R 132.22 and R144.19 per sheep from merinos in the Karoo, which suggests that wool yield can be increased. Expected weaning percentages for lambs in commercial herds range from 120-128% (Crettenden and Holbery, Undated; Schoeman et al., 2010), compared with 73% observed in Ntshiqo.
- Increase offtake or sales of livestock, which will reduce grazing pressure, increase livestock performance and income for farmers.

It is also interesting to note the estimated value of livestock manure as a fertiliser – a total value of R394 295 was the estimated value of manure in terms of the cost of the nutrients N, P and K. While farmers reported using manure for their homestead gardens, it would be interesting to demonstrate the value of this resource to them in terms of a Rand value. Strategies to enhance LWP are discussed in more detail in 5.9.6.

5.9.4 Supplementary feeding with a protein lick

The outcomes of the supplementary feeding experiment are discussed below.

Sheep which had access to the protein lick (treatment) and those without (control) had mean body condition scores of 1.80 and 1.54 in June, 1.76 and 1.35 in July, 2.01 and 1.48 in August and 2.03 and 1.53 in September, respectively (Table 5.41). A body condition score of 2 is required for maintenance of sheep (Grainer, 2012). During June, there was a significant difference ($t= 2.07$, $p<0.05$, $df= 102$) in the body condition scores of sheep in the treatment compared to those in the control. The mean difference in body condition was 0.26 ± 0.124 (Table 5.44). The body condition scores of sheep in the treatment were significantly higher in the months of July ($t= 4.17$, $p= <0.0001$, $df= 102$) with a mean difference of 0.41 ± 0.097, August ($t= 4.59$, $p= <0.0001$, $df= 102$) with a mean difference of 0.53 ± 0.115 and September

[5] Exchange rate of ZAR14 = USD1 is assumed.

(t= 4.13, p= <0.0001, df= 102) with a mean difference of 0.50 ± 0.120. Additional information was obtained from FGDs, revealing the responses of participants on effectiveness of the protein lick on improving the body condition of sheep (LWG, 2015). The LWG (2015) confirmed an increase in body mass and condition of sheep, reduced deaths and ewes produced sufficient milk yields for their lambs (LWG, 2015). Benefits were also realised in improved animal health and productivity, which resulted in improved livelihoods and vulnerability (LWG, 2015). The results obtained from the body condition scoring experiment indicate that a protein lick had a significant positive impact on the body condition of sheep (Figure 5.42). The response of the participants on the protein supplementation was positive, indicating that they wanted to continue this in subsequent years (LWG, 2015). This was important in ensuring the 'buy-in' of interventions by smallholder farmers, an integral part of improving LWP (Descheemaeker et al., 2009).

Table 5.41: Mean body condition scores of sheep in a control (n=50) and treatment (protein lick, n=54) over four months (June - September) at Ntshiqo, Eastern Cape

	Mean BCS Scores	Difference between means	Standard error for the difference between means (s.e.d.m)	sd	se	t-value	p-value
June Control (n=50)	1.54	0.26	0.124	0.613	0.087	2.07	0.021
June Treatment (n=54)	1.80			0.648	0.088		
July Control (n=50)	1.35	0.41	0.097	0.455	0.064	4.17	<0.0001
July Treatment (n=54)	1.76			0.539	0.073		
August Control (n=50)	1.48	0.53	0.115	0.562	0.079	4.59	<0.0001
August Treatment (n=54)	2.01			0.610	0.083		
September Control (n=50)	1.53	0.50	0.120	0.601	0.085	4.13	<0.0001
September Treatment (n=54)	2.03			0.625	0.085		

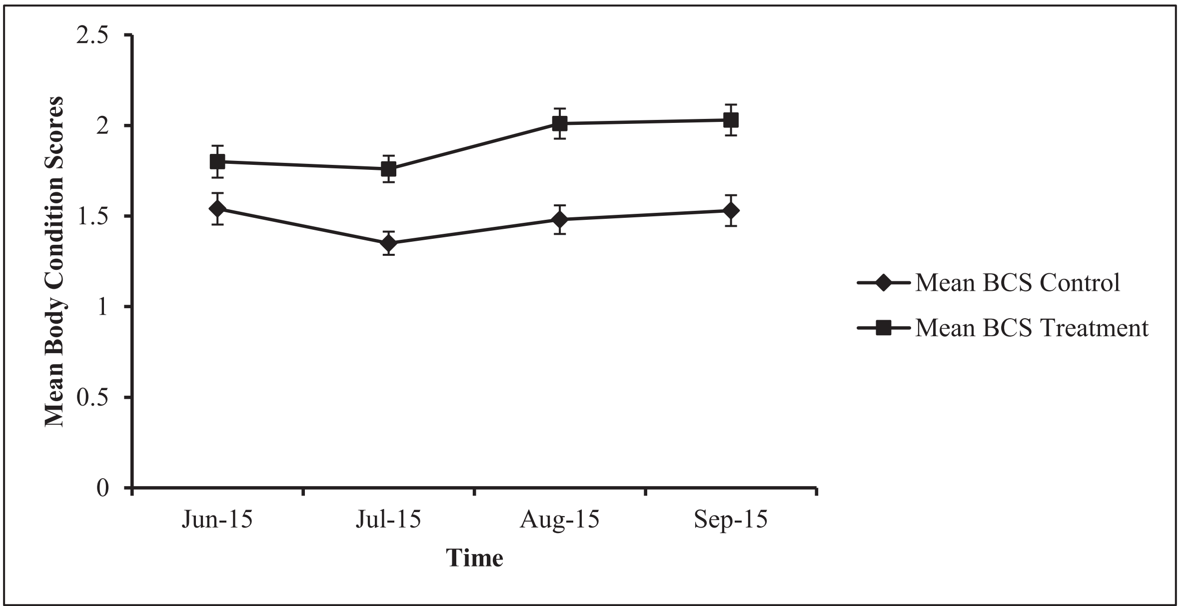


Figure 5.42: Mean (± se) body condition scores for sheep in a control and treatment over time (June - September) at Ntshiqo, Eastern Cape

Fodder crops can be utilised by livestock as another source of supplementary feed, to account for nutrient deficiencies and to improve animal production (Tau, 2005; Descheemaeker et al., 2009; Dube, 2012).

5.9.5 Fodder crops (vetch and oats)

Fodder crops play an important role in improving forage digestibility, intake and nutrient levels thereby aiding livestock production (Keftasa, 1988; Descheemeaker et al., 2010a; Yami et al., 2013). In Ntshiqo, four smallholder farmers were selected for RWH&C cropping trials and hence were also involved in the fodder crop supplementary feeding experiment. These fodder crops excelled at these sites. Livestock were given restricted access to the cultivated fields on a daily basis once the maize crop was harvested, to graze on the winter fodder crops.

The DM yields of vetch and oats were determined using calibrated disc pasture meter readings. The results are summarised in Table 5.42.

Table 5.42: DM Yield of vetch and oats from treatments at Ntshiqo, Eastern Cape

Homestead	DM Yield (kg/ha)	Garden Size (ha)	DM Yield from garden (kg)
Mjali	3 175.02	0.30	952.51
Beya	3 591.20	0.30	1 077.36
Quvile	3 882.16	0.30	1 164.65
Madosini	2 913.34	0.34	990.54

Dry matter yield from the demonstration sites was found to range between 3.17 $t.ha^{-1}$ and 3.88 $t.ha^{-1}$, giving a DM yield range of 952-1 164 kg at the homestead gardens.

Table 5.43: Yield of maize stover and vetch and oats at Ntshiqo demonstration sites 2014/2015

		Maize stover yield (kgDM/ha)	Vetch and Oats Yield (kgDM/ha)	Size of garden	Maize stover yield from garden (kg)	Vetch and oats yield from garden (kg)	Total DM available (kg)	Available DM per dayover 120 days	Number of LSUs supported	Number of SSUs supported
Mjali	Treatment	5,838	3,175.02	0.30	1,751	952.51	2,704	21.98	1.83	36.64
	Control	5,973		0.30	1,792	-	1,792	14.57	1.21	24.28
Beya	Treatment	3,013	3,591.20	0.30	904	1,077.36	1,981	16.11	1.34	26.85
	Control	5,101		0.30	1,530	-	1,530	12.44	1.04	20.73
Quvile	Treatment	2,072	3,882.16	0.30	622	1,164.65	1,786	14.52	1.21	24.21
	Control	3,414		0.30	1,024	-	1,024	8.33	0.69	13.88
Sokhombela	Treatment	4,214	-	0.22	927	-	927	7.54	0.63	12.56
	Control	1,943		0.22	427	-	427	3.47	0.29	5.79
Madosini	Treatment	2,387		0.34	812	-	812	6.60	0.55	11.00
	Control	3,009	2,913.34	0.34	1,023	990.54	2,013.71	16.37	1.36	27.29

Assumptions

A Large Stock Unit (LSU) of 400kg consumes 3% of body mass per day giving a daily intake of 12 kg/day

A Small Stock Unit (SSU) of 20kg consumes 3% of body mass per day giving a daily intake of 0.6 kg/day

While the maize stover yield was found to be higher in the control (Table 5.43), when including the fodder yield from vetch and oats, the total DM yield was found to be higher in the RWH&C treatment across all sites. Over a 120 day winter grazing period, it was calculated that this fodder from the homestead gardens, if managed correctly (i.e. controlled access to grazing on a daily basis) could support 0.29 – 1.83 large stock units (LSUs) and 5.79 – 36.64 small stock units (SSUs), depending on the fodder yield from the respective gardens (Table 5.43).

Both the ADF and NDF of the vetch and oats had mean values of 37.15 and 59.32% respectively, depicting relatively reduced fibre content compared to the rangeland (Table 5.44). Mean crude protein values (CP%) of 14.65% indicated high protein content (Mapako, 2011). Phosphorus values were low with a mean value of 0.21% (Mapako, 2011). The fodder crops thrived in the homestead gardens and participants expressed interest in these fodder crops as a future source of supplementary feed (LWG, 2015).

Table 5.44: ADF, NDF, Crude Protein and Phosphorus values for a mixture of vetch and oats at Ntshiqo, Eastern Cape

Homestead	ADF (%)	NDF (%)	Crude Protein (%)	Phosphorus (%)
Quvile	40.48	60.77	14.36	0.16
Sokhombela	35.36	56.58	15.02	0.20
Mjali	39.10	60.11	16.93	0.29
Madusini	33.66	59.80	12.41	0.17
Mean	37.15	59.32	14.68	0.21

Considering the relative importance of livestock to farmers in Ntshiqo (given the high proportion of maize grain used to feed livestock) and the higher grain yield and the higher total fodder yield associated with the RWH&C treatment, this practice can contribute substantially to livestock productivity in Ntshiqo if applied at a wider scale.

5.9.6 Discussion from rangeland and livestock research

Biomass production

All the resting experiments, namely the exclosures (17 months), short (4 months) and full (9 months) summer rests had a significant ($p < 0.05$) positive effect on biomass production. The longer the period of rest, the higher the biomass production. No significant ($p > 0.05$) difference was evident between the forage quality components (ADF, NDF, CP, P) between the exclosures and grazed areas in summer, winter and spring. In the rotational experiment, there was a significant ($p < 0.05$) difference between ADF in the full summer rest compared to the short summer rest. No significant ($p > 0.05$) difference was observed between the remaining forage quality components in the rotational resting experiment. Collectively, research participants revealed positive feedback from the various feed management interventions (resting, protein supplementation and fodder crops) applied throughout the study period. The following sections discuss the results obtained. Furthermore, appropriate management interventions are proposed to improve LWP at Ntshiqo.

Sourveld in South Africa constitutes a valuable resource by providing cheap grazing for cattle and sheep production (Kirkman and Moore, 1995). Sourveld in communal rangelands generally experiences high grazing pressure, low veld condition and poor carrying capacities (Martindale, 2007). This typically results in forage of low digestibility, intake and quality contributing to low productivity of livestock in South Africa (Tau, 2005). Fodder shortage and low quality forage especially during the dry winter season constrain livestock production (meat, milk, health, offspring, wool) in sourveld regions (Waters-Bayer and Bayer, 1992; Tau, 2005; Dovie et al., 2006). Therefore understanding the components of feed management (feed type selection, feed quality, feed water productivity and grazing management) is crucial in improving LWP in smallholder farming systems in South Africa, especially in the face of water scarcity and climate change (Descheemaeker et al., 2009; Descheemaeker et al., 2010a). The research focused specifically on feed quality and grazing management. The following sections discuss the findings of current practices and rangeland condition in Ntshiqo, the impact of resting on fodder quantity and quality, supplementary feeding and suggested management interventions for improved LWP. It is important in understanding community dependence and vulnerabilities, which guide the formulation of appropriate interventions to improve resilience and long-term improvement of LWP in smallholder mixed crop-livestock systems. Although not the focus, the integration of technical, institutional and policy aspects for improved LWP are discussed.

Veld condition is a measure of the health of the veld, in terms of susceptibility to erosion and its ability to provide forage for livestock (Trollope et al., 1990). Apart from health, it also indicates predominant functional grass types, and the degree and type of grazing pressure exerted on the system (Tainton, 1999). Currently in Ntshiqo, continuous grazing without a seasonal rest is practiced. It is evident that palatable climax species such as *Themeda triandra* are subject to high grazing pressure due to their palatability. Only Site 1 had a reasonable percentage of *Themeda triandra* (27.5%), with the other two sites having less than 6% respectively. Sites 2 and 3 were previously planted with crops and hence experienced an intense form of disturbance caused by ploughing. This is a form of rangeland degradation as it negatively affects the natural functioning of these ecosystems and animal productivity (Descheemaeker et al., 2009; Descheemaeker et al., 2010a), and has become a problem in the communal rangelands across South Africa (Everson et al., 2009). These species have decreased in abundance and are being replaced by less palatable species (Barnes, 1992; Kirkman and Moore, 1995; Snyman, 2006; Martindale, 2007). This type of degradation is common in sourveld regions of South Africa (Kirkman and Moore, 1995), and can be attributed to the low dispersal and germination success of these palatable species particularly in sourveld regions (Everson et al., 2009). Palmer and Bennett (2013) confirm that rangelands under common management in South Africa continue to experience transformation, as defined by species composition and productivity. Additionally, tillers have an upright rather than decumbent growth habit, contributing to the slow recolonization process (Everson et al., 2009). Therefore due to high grazing pressure, it may take these species a long time to return (Everson et al., 2009). The restoration of grasses such as *Themeda triandra* is important to increase livestock production for dryland smallholder farmers and conserve biodiversity (Everson et al., 2009). The Increaser II species were the most common grass species with a composition exceeding 60% across the three sites (Table 5.25). These species increase in abundance with severe overgrazing (Tainton, 1999; Descheemaeker et al., 2010; Van Oudtshoorn, 2012), with the results indicating overgrazing over an extended period of time in Ntshiqo. The species compositions indicate uniformly poor veld conditions with an average 41.01%. The study showed a recommended stocking density of 436 AU, compared to the current 1 666 AU, which is just under four times the recommended stocking density. It is evident that stocking densities are not being controlled. Poor veld condition, coupled with a high stocking density, has resulted in low grazing capacities across the sites, with an average of 0.30 $AU.ha^{-1}$ reduced from a potential grazing capacity of 0.67 $AU.ha^{-1}$. This has reduced the carrying capacity and potential of the land to support a large number of animals (Table 5.26) (Munyai, 2012). The results indicate that the Mthatha Moist Rangeland in Ntshiqo is degraded, possibly due to historic overgrazing (Martindale, 2007; Mapako, 2011). To prevent economic losses due to poor livestock production, farmers need to reduce livestock numbers or adopt a form of resting regime (Mapako et al., 2011). The tested technical interventions implemented in Ntshiqo can inform the management practices of the smallholder farmers, which potentially have the ability to curb negative impacts of overgrazing and high stocking densities, and ultimately improve the natural functions of the ecosystem and rangeland, animal productivity and overall LWP (Descheemaeker et al., 2010a; Mapako et al., 2011).

Forage quantity

<u>Exclosures and grazed areas</u>

The results showed significant differences in biomass production between all the exclosures and grazed areas. The grazed areas reached peak biomass earlier (March and April) compared to the exclosures (May), due to the effect of grazing by livestock, especially leading into winter. Biomass decreased in the exclosures in June, following the first frost (Figs 4.1-4.3). In the peak growing period (May), the exclosures produced a mean difference of 1.35 $t.ha^{-1}$ more biomass than the grazed areas ($p = 0.001$), with a mean maximum biomass production of 2.57 $t.ha^{-1}$ (Table 4.4). This depicted a four-fold increase in biomass production in the exclosures compared to the initial values at the start of the experiment. At the end of the growing season (August) exclosures produced a mean difference of 1.52 $t.ha^{-1}$ more biomass than the grazed areas ($p = 0.0002$). This was done for the purpose of achieving research objective 2 which was to analyse the feed management component of the LWP framework by investigating the effect of resting on the quantity and quality of fodder produced from rangelands at the case study site. Biomass production was low for all the continuously grazed sites (<2.1 $t.ha^{-1}$). Mapiye et al. (2009) state that feed shortage was the biggest constraint to cattle production in smallholder farming systems in the Eastern Cape of South Africa. This showed the benefits of total exclosure of portions a rangeland by increasing the above ground biomass production which serves as additional feed for livestock (Descheemaeker et al., 2009; Mapako, 2011). This has important implications for improving net livestock benefits such as food production (milk, meat) (Pratt, 1984; Waters-Bayer and Bayer, 1992; Smith et al., 2013; Okungoya, 2014), raw materials such as wool (De Beer, 2012), provision of draught power (Waters-Bayer and Bayer, 1992; Dovie et al., 2006; Tarawali et al., 2011), which can lead to resilience against external shocks in smallholder farming systems.

The mean difference in biomass production was the lowest for Site 1 in May and August, which had the highest percentage of *Themeda triandra* composition. This indicates a reduction in the vigour of the plants (Kirkman and Moore, 1995). With no appropriate rangeland management techniques implemented in Ntshiqo, it is evident that repeated defoliation of these palatable species is occurring during the growing season, which is detrimental to the vigour of plants (Barnes, 1989c; Barnes and Dempsey, 1992). According to Martindale (2007), there is an inverse relationship between *Themeda triandra* and stocking density and a direct relationship in species such as *Sporobolous africanus*. This reinforces that Decreaser species would be expected to decline in abundance with increasing grazing pressure (Martindale, 2007). Evidence suggests that the intensity, frequency and timing of defoliation have a greater impact on the vigour of plants compared to the grazing system (Barnes, 1989c; Barnes and Dempsey, 1992).

The biomass produced in Site 2 and 3 were both significantly higher than in Site 1. This, however, does not necessarily translate into more productive veld that provides livestock with higher feed quantity. On the contrary, these areas depict lower veld condition and grazing capacities compared to Site 1. Dominant grasses have become moribund and died out through self-shading, which have been succeeded by less palatable (Increaser II) species (Morris and Tainton, 2002). Therefore these areas are preferred less by livestock, due to the maturity of less palatable species making them unacceptable for consumption (Tainton and Danckwerts, 1989).

The type and ratio of livestock contributes to the overall management interventions required. Sheep and cattle graze veld differently. Sheep prefer short, leafy grass, free of moribund material whereas cattle graze more uniformly and less intensively than sheep, and perform satisfactorily on veld which is relatively mature (Barnes, 1992; Kirkman and Moore, 1995). Sheep can be detrimental to rangelands through continued selective overgrazing, by removing or reducing the vigour of the palatable species creating a vacuum which is filled by less desirable species (Barnes, 1992). According to Barnes (1989a), the yields of *Themeda triandra* in the season after the one in which the veld was grazed intensely by sheep, were only 48% of those rested in the previous season. This grazing negatively influences the regrowth potential by reducing the amount of stored reserves, and reducing the amount of growing points on plants (Lütge et al., 1996). In sourveld regions, selective grazing may initiate the rangeland degradation process from which arguably overall rangeland degradation proceeds (O'Reagain and Turner 1992; Lütge et al., 1996). Therefore sheep and cattle should be grazed together to ensure uniform grazing of the veld (Hardy et al., 1994; Martindale, 2007). Cattle remove tall, relatively mature grass material thereby simulating new growth from a large portion of plants which would otherwise be rejected by sheep (Hardy et al., 1994). Therefore it is important to have a mixed species grazing regime, consisting of a higher cattle-to-sheep ratio, to reduce selective grazing (Martindale, 2007). Currently in Ntshiqo there is a 1:5 cattle-to-sheep ratio. This explains the high degree of grazing pressure especially at Site 1, as sheep prefer the palatable grass species, potentially contributing to poor veld conditions and carrying capacities. This long term rest (17 months) increased forage quantity to a mean of 2.57 $t.ha^{-1}$ across the three sites. Increasing the forage quantity in an area of forage deficit is important for livestock production in smallholder mixed crop-livestock systems (Descheemaeker et al., 2009; Everson and Smith, Undated). Implementing rangeland management techniques, such as rotational resting, is important for long term veld and animal productivity, especially in communal smallholder farming systems in South Africa (Tainton, 1999; Tainton and Danckwerts, 1999; Smith, 1997; Descheemaeker et al., 2010a).

<u>Rotational resting</u>

The short and full summer rests reflected a mean biomass production of 0.84 and 1.97 $t.ha^{-1}$, which is a two-fold and five-fold increase in biomass production respectively, compared to the initial biomass values at the start of the experiment. The rotational resting experiment indicated that biomass produced in a full summer rest is significantly higher ($p=0.013$) compared to a short summer rest, with a mean difference of 1.35 $t.ha^{-1}$. Grazing during the growing season has revealed that livestock can have a severe negative impact on both the vigour and species composition of veld (Kirkman, 2002a; Kirkman, 2002b). According to a review of grazing research in South Africa, sustained heavy stocking densities in sourveld regions has a negative impact on vegetation, particularly its ability to recover after grazing (O'Reagain and Turner, 1992; Tau, 2005). During the dormant season, grazing has a negligible effect on the vigour of plants (Kirkman and De Faccio Carvalho, 2003). Results from Barnes and Dempsey (1992) and Peddie et al. (1995), indicate that a rest for a full growing season is adequate for the vigour of plants to recover. Contrastingly, Lütge et al. (1996) argue that in sourveld regions over a number of grazing cycles, the vigour of plants may not recover sufficiently during a full summer rest due to constant depletion of stored reserves. A study conducted by Morris et al. (1992) in the Southern Tall Grassveld of KwaZulu-Natal, indicated an invasion of *Aristida junciformis* (Increaser III) after a continuous grazing scheme at high stocking rates was interrupted by a full summer rotational rest. However, a full summer rest benefits the entire plant production and provides an uninterrupted period of development to renew energy reserves, which is vital for the health and survival of plants (Undersander et al., 1993; Tainton and Danckwerts, 1999). During spring, leaf and above-ground biomass production is favoured (Tainton and Danckwerts, 1989; Smith, 1997). This provides an uninterrupted period of photosynthesis, to produce sufficient carbohydrates and replace those utilised to initiate spring growth (Tainton and Danckwerts, 1989). In summer, seed production is promoted as well as vigour and productivity of veld (Tainton and Danckwerts, 1989; Kirkman and Moore, 1995). Root production is favoured during autumn (Smith, 1997; Snyman, 2006). A full summer rest provides sufficient time to improve root mass, build-up and storage functions (Snyman, 2006). Good root production improves the resilience of a plant to drought, improves the capacity of obtaining minerals from the soil, promotes biomass production and potentially improves veld condition (Undersander et al., 1993; Snyman, 2006). Regular full summer rests should be implemented to improve vigour of plants, seed, root and biomass production of palatable species (Teague et al., 1981; Kirkman and Moore, 1995; Snyman, 2009). Simultaneously improving these variables promotes ecosystem functioning through the prevention of land degradation, especially soil erosion, which ultimately can result in rehabilitation and improved rangeland productivity, water conservation and improved hydrological processes, thereby improving livestock production and contributing to the overall improvement of LWP (Kirkman and Moore, 1995; Descheemaeker et al., 2006; Thornton et al., 2009; Thornton and Herrero, 2010). Smallholder farmers are dependent on livestock production (Waters-Bayer and Bayer, 1992). Improving livestock production is important through increasing food production, raw materials and resilience against water scarcity and climate change for the livelihoods of smallholder farmers (Thornton and Herrero, 2015). Therefore resting is vital not only for increasing forage quantity but also for the natural functioning of ecosystems, which aids long-term livestock production in mixed crop-livestock systems in developing countries (Descheemaeker et al., 2009).

Forage quality

Exclosures and grazed areas

Understanding nutrient content of plants is vital for animal production (Munyai, 2012). Nutrient analysis can be used to determine whether forage quality is sufficient for animal production and to indicate whether supplementation is required (Ball et al., 2001). The ADF and NDF values in the exclosures and grazed areas were not different ($p > 0.05$) in February and June (Table 5.28 and Table 5.29). The overall mean ADF values in the exclosures and grazed areas ranged from 45.66-51.17% (Table 5.28). ADF is inversely related to digestibility. The ADF values were high indicating low energy, poor feed quality with a low digestibility

(De Bruyn and Koster, 2000; Newman et al., 2006; Mapako, 2011). These high values indicate mature forage, with a high percentage of indigestible plant material such as lignin and cellulose, with low energy content (Beauchemin, 1996; Ball et al., 2001). Robinson et al. (1998) state that an NDF value greater than 45% reduces forage quality significantly. Hemicellulose and cellulose are slowly digested by ruminants, whereas lignin is indigestible (Beauchemin, 1996). The NDF percentage in feed determines the forage intake of an animal, through an inverse relationship (Newman et al., 2006). Therefore due to high percentages, feed intake of animals is low potentially decreasing the average daily gain in animals, negatively affecting livestock production (Tainton and Danckwerts, 1989). According to Meissner et al. (1999), feed intake is twice as important as digestibility in determining animal performance. Both ADF and NDF values are high, depicting forage with a high fibre content, low energy, digestibility and intake, reducing the overall palatability and forage quality of feed (Trollope et al., 1990; Ball et al., 2001). This reinforces the need for animals to graze palatable species or plant material (leaf and new growth), in an attempt to maintain body condition (Hatch, 1991).

The CP values in the exclosures and grazed areas were not different ($p > 0.05$) in February and June. The overall mean CP values ranged from 2.33-5.80%. These are low values which are below animal requirements (Newman, 2006; Mapako, 2011; Munyai, 2012). Protein is undoubtedly the primary limiting nutrient in the diet of livestock (Van Niekerk and Jacobs, 1985; Ball et al., 2001). In sourveld, during the winter months, the drop in the quality of the veld becomes the most limiting factor and intake of livestock declines (Danckwerts, 1989; Sprinkle, 2001; De Bruyn and Koster, 2000; Kirkman and De Faccio Carvalho, 2003). If CP is deficient in livestock diets, rumen microbes will be unable to degrade fodder especially that of poor quality, hence a decrease in forage intake (Ball et al., 2001; Newman et al., 2006). This can result in weight loss and reduced productivity as livestock must break down tissue to supply the required protein (Sprinkle, 2001). CP was below 6.25% therefore it is evident that livestock in Ntshiqo require protein supplementation, especially over the winter months to account for poor forage quality and protein deficiencies of fodder (Sprinkle, 2001). Providing protein supplementation is vital to increase forage intake and digestibility, lactation, reduce weight loss before calving and ultimately increase conception rate, livestock production and profitability (Lalman, undated; Sprinkle, 2001).

The P concentrations in the exclosures and grazed areas were not different ($p > 0.05$) in February and June. The overall mean P concentration ranged from 0.04-0.12%. This indicates low P values, which are below animal requirement, as a lactating cow requires 0.27% P in a pasture (NRC, 1984; Mapako, 2011). P is the second most important and limiting plant nutrient in forage (Van Niekerk and Jacobs, 1985; Miller and Gardiner, 1998). The nucleus of each plant cell contains P therefore cell division and growth depend on adequate amounts of this element for plant production (Oliver, 2007). P is required for the functioning of energy metabolism in livestock, ensuring conception rates and milk production (De Brouwer et al., 2000; De Bruyn and Koster, 2000). P supplementation has been found to increase animal performance during periods when animals are gaining body mass, however when fed in isolation, cannot prevent the loss of animal condition during the winter months (Van Niekerk and Jacobs, 1985). This form of supplementation is most effective when combined with protein (Van Niekerk and Jacobs, 1985). Improving forage quality is significant in terms of digestibility, forage intake and nutrient content, which aids livestock production and overall LWP (Van Niekerk and Jacobs, 1985; De Brouwer et al., 2000; Descheemaeker et al., 2010a; Descheemaeker et al., 2011).

Rotational resting areas

The ADF values in the full and short summer rotational resting experiments were ($p = 0.004$). The ADF values in the full summer rest had a higher mean difference of 4.02 % compared to the short summer rest. No clear reasons were evident as to why there was a significant difference in ADF values between the rotational resting experiments and not the exclosures and grazed areas. This is potentially one negative aspect of resting, in that no defoliation takes place, plants mature, increasing cell wall contents such as cellulose and lignin, thereby decreasing the digestibility of forage (Beauchemin, 1996; Ball et al., 2001; Newman et al., 2006; Mapako, 2011). The positive aspects of resting do outweigh the negatives, in providing an uninterrupted period of growth for entire plant development, which ultimately improves plant vigour, production and resilience to defoliation (Tainton and Danckwerts, 1989; Kirkman and Moore, 1995; Snyman, 2006). The NDF, CP and P values in the full and short summer rotational resting experiment were not significantly different ($p > 0.05$). The NDF values are high, again indicating mature plant material with high fibre content. Both the CP and P values were below animal requirement (Mapako, 2011). It is evident that a half and full summer rest have no significant effect on the forage quality of plants but are critical for biomass production, overall plant development and restoration of vigour.

Supplementation with a protein lick

During winter in sourveld regions in South Africa, the drop in forage quality is the most limiting factor which negatively influences intake (O'Reagain and Mentis, 1988; Danckwerts, 1989; De Bruyn and Koster, 2000; Kirkman and De Faccio Carvalho, 2003). Protein typically drops below animal requirements during the dry season (Mapako, 2011). The results of the protein supplementation (Voermol Protein Lick) experiment in June depict a significant difference between sheep in the treatment and control ($p < 0.05$) (Table 5.41). A study conducted by Mvinjelwa et al. (2014) in the Eastern Cape Province of South Africa, confirms that protein supplementation over the winter months in sourveld areas positively affects the body condition of sheep. This was done for the purpose of achieving research objective 3 which was to analyse the effect of protein supplementation on the body condition score of sheep at the case study site. Highly significant differences ($p < 0.0001$) and larger mean differences in body condition scores were recorded for sheep in the treatment compared to the control from July to September. This indicates that protein supplementation becomes more effective over longer periods of utilisation (Sprinkle, 2001). Data obtained in the FGDs for the current research, revealed that protein supplementation had numerous positive effects on sheep in the treatment (LWG, 2015). Firstly, there was an increase in body mass and body condition of sheep (Ball et al., 2001; Sprinkle, 2001). Additionally reduced deaths occurred, indicating that the sheep were not losing body condition (LWG, 2015). Lactation places the greatest nutrient demands on animals (Ball et al., 2001). Lastly, the ewes produced sufficient milk yields for their lambs which are critical for survival and growth (Ball et al., 2001; LWG, 2015). According to Moore and Müller (1994), pregnant ewes can successfully be wintered on poor quality grass, through protein supplementation, at a low cost. Evidence indicates that sufficient supplementation improves conception and lambing percentages (O'Reagain and Mentis, 1988; Sprinkle, 2001). According to a study conducted by Van Niekerk and Jacobs (1985), protein supplementation has a significant effect on poor quality forage intake by livestock. Protein licks and supplementary feed should never substitute feed, but rather supplement poor quality feed (Cleasby, 1963; De Bruyn and Kosta, 2000; Ball et al., 2001). This is to account for nutrient deficiencies, ensure optimal utilization of feed, reduce weight loss and hence improve animal performance and productivity (health, milk and meat production). The participants of the protein lick experiment were all satisfied with the positive results obtained (LWG, 2015). A community member participating in the trial stated: "I will carry on feeding my sheep with a protein lick next year over winter" (LWG, 2015: personal communication). This promoted important 'buy-in' of the community in potentially adopting such a technical intervention for improving long-term livestock productivity and LWP in Ntshiqo (Deschemaeker et al., 2009). This is an important intervention in improving LWP (Descheemaeker et al., 2010a), and is detailed in the next section.

Recommended management interventions

The veld in Ntshiqo is highly overgrazed, characterised by forage quantity deficiencies and veld of poor quality, hence interventions such as fire, rotational resting and re-seeding are required to promote the growth of more palatable species and improve the overall veld condition of the veld (Everson and Tainton, 1984; Kirkman and De Faccio Carvalho, 2003; Everson et al., 2009). Additionally, protein supplementation and the introduction of fodder crops (vetch and oats) were assessed in terms of improving forage quality and intake (Assefa and Ledin, 2001). It is considered that the technical management interventions (implemented and proposed) discussed below are viable and could be beneficial in aiding the correct management of sourveld, improving livestock production and LWP (Kirkman and Moore, 1995; Descheemaeker et al., 2009; Descheemaeker et al., 2010a; Descheemaeker et al., 2011). It is important to focus on interventions that can bring real benefits and improve livelihoods in smallholder farming systems (Amede et al., 2009). This was done for the purpose of achieving research objective 4, which was to determine the influence of these specific management interventions on LWP, and the implications for the environment and livelihood dependencies of smallholder farmers

<u>Role of fire</u>

Fire plays an important role in the maintenance of sourveld (Kirkman and Moore, 1995). Controlled burning of sourveld during the dormant season or early spring is an accepted practice (Barnes, 1992). The main objectives of burning are to remove mature, moribund and dead plant material and promote new palatable growth (Trollope, 1989; Barnes, 1992; Marx, 2001; Morris and Tainton, 2002; Mapiye et al., 2008; Everson et al., 2009). This can be used to reduce selective grazing and promote uniform utilisation of the veld (Kirkman and Moore, 1995). Sourveld areas require regular burning especially in areas of low utilisation where growth conditions are favourable (Trollope, 1989). This reinforces the need of fire intervention especially as Sites 2 and 3, which are characterised by moribund and unpalatable growth, poor species composition and veld condition.

In a study conducted in the Cathedral Peak area in KwaZulu-Natal, Everson and Tainton (1984) found that a regular fire regime maintained sourveld veld condition whereas protection from fire resulted in a 42% drop in veld condition. The treatment means for Decreaser species were 48.8% in the annual winter burning, 36.6% in the biennial spring burning and 26% in the protected treatments (Everson and Tainton, 1984). Another study conducted in the Cathedral Peak area by Everson et al. (2009), revealed that a biennial spring burn increased seed production of *Themeda triandra* which promotes the spread of this species, thereby improving rangeland condition. A biennial spring burn provides enough time for the growth of reproductive tillers and avoids damaging plants during the important summer growth season which would negatively affect reproductive the output (Everson et al., 2009). This reinforces the fact that *Themeda triandra* is a fire-climax species (Everson et al., 2009). Additionally, the majority of grass species would be palatable in the early season following fires, thereby promoting intake of forage and livestock productivity (Martindale, 2007).

In Ntshiqo, the role of fire in rangeland management is misunderstood, and is associated as a negative factor which reduces the amount of forage available for animals (LWG, 2015). On the contrary, if certain areas of the rangeland are not burnt, fodder availability and intake will decrease further, due to the presence of mature, indigestible forage of poor quality. Therefore institutional change is required in Ntshiqo (Amede et al., 2009), so that burning can be used as a tool to improve veld condition, digestibility and vigour of forage, and to ensure correct rangeland management (Everson and Tainton, 1984; Kirkman and Moore, 1995; Mapiye et al., 2008). When a new technical intervention is introduced some degree of institutional change is required to improve components of the LWP framework (Amede et al., 2009; Descheemaeker et al., 2010a). Replacing old paradigms formulated by traditional authorities, with new management techniques remains a challenge in communal smallholder farming systems in South Africa (Lemaire et al., 2014; LWG, 2015). Nevertheless, a biennial spring burn is recommended and veld should not be grazed within 6 to 8 weeks of burning or until it has recovered to a height of 100 mm to 150 mm (Trollope, 1989; Trollope, 1999).

Grazing and resting

Resting of veld is one of the most important management interventions recommended for all types of veld (O'Reagain, 1994; Tainton and Danckwerts, 1999; Descheemaeker et al., 2006). This can aid in maintaining long term veld and animal production (O'Reagain, 1994; Tainton and Danckwerts, 1999). In Ntshiqo, controlling the movement of livestock should ensure uniform utilization of the rangeland (Tau, 2005). Three different resting experiments were initiated in Ntshiqo, namely a long term rest (17 months), a full (9 months) and short (4 months) summer rest. Research on resting in smallholder communal rangelands in South Africa is lacking (Shackleton, 1993), hence this information is valuable in filling this research gap. The longer the rest applied, the higher the forage quantity produced. However proposing appropriate grazing management interventions for communal rangelands, requires a consideration of production objectives (Kotze et al., 2013). The production objectives in communal rangelands, focus on high animal numbers that account for multipurpose livelihood benefits (draught, food production, manure, cultural purposes, cash income), compared to commercial systems which are focused purely on high turnovers and profit (Waters-Bayer and Bayer, 1992; Masika et al., 1998; Kotze et al., 2013). To support high animal numbers and hence obtain net livestock benefits, continuous full summer rotational rests are proposed especially for Site 1 in Ntshiqo. This is to allow palatable plant species to improve their vigour and biomass, which positively contributes to the natural functioning and condition of rangelands, and promotes long-term livestock production (Teague et al., 1981; Trollope et al., 1990; Kirkman and Moore, 1995; Snyman, 2006; Descheemaeker et al., 2009). Community members had appointed rangers to exclude livestock from the rested area (LWG, 2015). This system was successful and is advised for subsequent years (LWG, 2015). The FGDs revealed a positive response from Ntshiqo community members regarding rotational resting (LWG, 2015), which is vital, because without 'buy-in' such technical interventions will not be successful (Amede et al., 2009). However, there are no fences in Ntshiqo which may pose as a problem in controlling animal movement in the long term (Munyai, 2012). The reduction of grazing during the growing season is critical in terms of correct rangeland management. Heavier utilisation of the veld during the dormant season (after first frost and before spring growth) is advised coupled with protein supplementation to account for nutrient deficiencies (Kirkman and Moore, 1995; Kirkman and De Faccio Carvalho, 2003). Improving the grazing management component of the LWP framework (Descheemaeker et al., 2010a), contributes significantly to the overall feed management, and hence the net livestock benefits (Pratt, 1984; Waters-Bayer and Bayer, 1992; Dovie et al., 2006; Tarawali et al., 2011; De Beer, 2012; Smith et al., 2013; Okungoya, 2014). Such benefits produced from livestock improve the resilience of smallholder farmers against shocks such as drought, crop failure, water scarcity and climate change in smallholder farming systems (Kazianga and Udry, 2006; Stringer, 2009; Tarawali et al., 2011; Turpie and Visser, 2012; Vrieling et al., 2014; Thornton and Herrero, 2015). The majority of mixed crop-livestock systems in South Africa are rainfed, hence food security and livelihoods are threatened by climate change (Turpie and Visser, 2012). Rangelands in South Africa are expected to decline in productivity due to changing rainfall patterns and temperatures. Therefore, there is a need to implement effective grazing management strategies to improve net livestock benefits against external vulnerabilities.

Re-seeding

Themeda triandra has poor dispersal ability and it can take a long time for this species to return to an area. Therefore actively harvesting seeds is an essential management intervention in re-introducing this species to areas where it has disappeared. Additional research is required to increase seed longevity and to store seeds in a dormant stable state. A reseeding rehabilitation programme could be beneficial in restoring lost palatable species in degraded areas such as Ntshiqo (Everson et al., 2009). A possible way forward is to facilitate collaboration between smallholder farmers, Non-Governmental Organisations (NGOs), Non-Profit Originations (NPOs) such as the INR and local government end extension staff which can provide solutions to current problems (Descheemaeker et al., 2009; Descheemaeker et al., 2011). In South Africa, extension staff have been found to be limited in their capacity to deliver support services and resources to smallholder farmers (Vink and Kirsten, 2003; Williams et al., 2008). In Ntshiqo, extension staff provided insufficient support in terms of providing information and educating community members on possible management interventions to improve rangeland, crop and livestock production (LWG, 2015). Nonetheless, re-seeding remains an option in increasing palatable grass species composition, positively influencing rangeland condition and hence livestock production and LWP.

Protein supplementation

A protein lick is a relatively inexpensive form of supplementary feed (Akbar et al., 2006) therefore delaying the introduction of such a management intervention to save money is merely false economics and can only reduce animal production in the long term (O'Reagain and Mentis, 1988). Although biomass production is low in Ntshiqo, forage is available throughout the entire year, making protein licks a viable form of supplementation. The supplementation experiment promoted sheep production during the winter months by enabling animals to consume forage of poor quality. Making unpalatable feed acceptable and digestible can be the difference between life and death for livestock. As stated earlier, the protein supplementation had a significantly positive effect on the body condition score of sheep. This was important in terms of improving the forage quality under the feed management component of the LWP framework (Descheemaeker et al., 2009; Descheemaeker et al., 2010a) Additionally, the response from the participants was positive (LWG, 2015), which is vital for the long-term adoption of such a technical intervention, that contributes to the improvement of LWP (Amede et al., 2009).

Use of fodder crops (vetch and oats)

In addition to protein licks, fodder crops were introduced to smallholder farmers in Ntshiqo. In the majority of smallholder regions in South Africa, livestock are fed entirely on low quality veld or maize stover during winter months (Tau, 2005). Fodder crops have shown to increase the intake, digestibility and quality of forage that livestock consume (Keftasa, 1988; Descheemaeker et al., 2010a). Providing good quality forage is key for any livestock production system (Newman et al., 2006). Improving the digestible protein and nutrient content are important in improving animal productivity (Eskandari et al., 2009). Fodder crops are key components which influence feed management and livestock productivity. Selecting suitable feed type for livestock is an important component of feed management which has the potential of increasing LWP (Descheemaeker et al., 2009; Descheemaeker et al., 2010a). Growing compatible vetch and oats mixtures can be practically relevant in increasing forage productivity per unit area, digestibility, crude protein content and the intake by livestock (Assefa and Ledin, 2001). Both the mean ADF and NDF values were less than 45 and 65% respectively, indicating lower fibre content aiding improved digestibility and forage intake (De Bruyn and Koster, 2000; Newman et al., 2006; Mapako, 2011; Munyai, 2012). Mean CP values of 14.65% are well over the minimum required level of 7% to meet the requirements of rumen microbes to digest fibre (Sprinkle, 2001; Munyai, 2012). This will aid livestock in Ntshiqo to digest the poor quality veld. A study conducted in the Free State in South Africa during winter indicated that gestating cows subjected to vetch pastures, significantly reduced the required forage intake due to increased levels of digestible protein (Fair, 2013). P concentration values were low with a mean value of 0.21%, however, these values are not as important as the required CP values (Van Niekerk and Jacobs, 1985; Mapako, 2011). The cultivation of vetch and oats is a viable option for improving forage intake and CP levels, aiding the utilisation of poor quality veld. Furthermore, it can reduce additional expenditure normally spent on other protein supplementation, especially in smallholder farming systems with limited inputs such as Ntshiqo (Eskandari et al., 2009; Yami et al., 2013). Vetch and oats cultivation can significantly improve the nutrient content in the diet of livestock, alleviate feed deficit, promoting and maintaining animal production during winter and positively contributing to overall LWP (Tau, 2005; Descheemaeker et al., 2010a). Again, the response from the participants in the fodder crop experiment was positive (LWG, 2015). A local farmer stated: “the fodder crops improved the production of my lambs and ewes over the winter months” (LWG, 2015: personal communication). It is important for farmers to observe positive influences of technical interventions, as this promotes the long-term adoption of these techniques. This was important in promoting the forage quality and feed type selection component of the LWP framework in Ntshiqo.

Collective management for improved LWP

Technical interventions such as rotational resting (Tainton and Danckwerts, 1999; Kirkman and Moore, 1995), protein supplementation (Van Niekerk and Jacobs, 1985; Sprinkle, 2001) and the introduction of fodder crops (Assefa and Ledin, 2001) showed benefits to livestock owners These aspects formed part of the feed management component of the LWP framework (Descheemaeker et al,. 2009; Descheemaeker et al., 2010a; Descheemaeker et al., 2011).

The resting experiments significantly increased forage quantity, which has the potential to increase livestock production in smallholder mixed crop-livestock farming systems (Everson and Smith, Undated; Tainton and Danckwerts; 1989). Through protein supplementation, the body mass and condition of sheep improved, as well as milk yields and reduced deaths over the winter period (LWG, 2015). Fodder crops (vetch and oats) were seen as an additional form of supplementary feeding which could improve animal productivity through better feed quality. The successful implementation of the specified feed management components of the LWP framework (Descheemaeker et al., 2010a), were important in improving the livelihoods of smallholder farmers in Ntshiqo. Net livestock benefits can be used by smallholder farmers to increase resilience against external shocks (water scarcity, drought, and climate change). Livestock can act as a source of security and insurance (Kazianga and Udry, 2006; Vrieling et al., 2014). Therefore it is evident that technical interventions can improve livestock and rangeland production and hence LWP in smallholder farming systems in developing countries (Amede *et* al., 2009; Descheemaeker et al., 2009; Descheemaeker et al., 2010a, Descheemaeker et al., 2011).

As previously stated, the overall response of Ntshiqo inhabitants in relation to the implemented technical feed management interventions was positive (LWG, 2015). Ensuring 'buy-in' from local smallholder farmers was a key step promoting adoption. Obtaining the support from these farmers was the most important aspect in implementing interventions aimed at improving LWP, because without their support no intervention would be viable (Amede et al., 2009). All of the implemented interventions were relatively cheap which is vital for adoption, especially in resource poor smallholder mixed crop-livestock systems such as Ntshiqo. For these technical interventions to be successful a degree of change was required.

Behavioural change is thus required through appropriate institutional structures which are classified as traditional authorities in Ntshiqo (North, 1993; Hodgson, 2006). Institutions are essential in introducing change, as they are the rules which govern a society (North, 1993; Amede et al., 2009). Rules within social institutions should not be rigid but fluctuating through time and space, as conditions change (drought, disease) and new opportunities emerge (Cleaver, 2000). The actions of people are influenced by the structural characteristics of societies in which they were brought up (Cleaver, 2000). Therefore effective institutional policies should govern crop, livestock and natural resource management in smallholder farming systems, so that a culture of correct management can be embedded into successive generations (Amede et al., 2009; Descheemaeker et al., 2009). In Ntshiqo, traditional authorities need to develop policies that promote and support the adoption of feed management interventions in years to come. This is in response to ineffective extension staff (LWG, 2015). These need to be built on the momentum gained from introducing new interventions such as those tested in this research, in Ntshiqo. Numerous studies (Amede et al., 2009; Descheemaeker et al., 2009; Descheemaeker et al., 2010a, Descheemaeker et al., 2011) have indicated that the implementation of technical interventions need to be accompanied by appropriate institutional structures and supportive policies. Such collaborative or integrative management, will ensure long term crop, livestock, land and water management which are crucial in improving LWP in smallholder mixed crop-livestock farming systems (Descheemaeker et al,. 2009; Descheemaeker et al,. 2010a, Descheemaeker et al., 2011). Furthermore, this can improve the resilience of these South African rain-fed smallholder systems to vulnerabilities such as poverty, crop failure, water scarcity and climate change (Tulu, 2006; Helmreich and Horn, 2009; Turpie and Visser, 2012; Thornton and Herrero, 2015).

6 REQUIREMENTS AND OPPORTUNITIES FOR OUTSCALING OF RWH&C

This chapter discusses the various requirements for outscaling RWH&C. Outscaling was not tested as part of the research and recommendations are therefore based on observations while conducting research, feedback from research participants through interviews and FGDs and biophysical assessments conducted at the project sites. Organisations and programmes providing support to agriculture are discussed first, followed by outcomes of the various engagements with stakeholders. The chapter concludes with a discussion of the factors that impact on outscaling.

6.1 Organisations providing support to agriculture at the research sites

This section elaborates on the government, non-government and local organisations providing support to agriculture.

6.1.1 Organisations providing support in Ntshiqo

Eastern Cape Department of Rural Development and Agrarian Reform

In Ntshiqo, the ECDRDAR is the Provincial Department responsible for agricultural support and development in the Eastern Cape. There are two main sections providing support to farmers, namely the Stock Control Officers, who operate under the Provincial State Veterinary Department which deals with livestock matters and the Agricultural Development Technicians (ADTs) or Extension Officers (EOs), who deal with crop production.

The stock control officers are responsible for dipping and inoculation of livestock against notifiable diseases. Dipping to control ticks reduces the risk of Redwater (Bovine Babesiosis) and Heartwater (Cowdriosis), two of the major tick-borne diseases occurring in South Africa. In addition, the Department provides the following inoculations:

- Cattle are inoculated against Blackquarter (or Quarter evil - *Clostridium chauvoei*) and Anthrax (*Bacillus anthracis*) on an annual basis (Blanthrax is the brand name of the vaccine used).
- Sheep are injected against sheep scab mite.
- Dogs are inoculated against rabies on an annual basis.

The Stock Control Officers do not provide support for rangeland and grazing management.

In terms of crop production, the Department has extension control technicians and assistant extension control technicians whose job it is to should provide extension support to crop and vegetable farmers. Farmers in Ntshiqo, who were interviewed, however indicated that it is rare that extension officers visit individual farmers, unless they are requested to do so. This is in part due to a lack of human resources on the part of the Department. One extension support technician and one assistant technician provide support to Ntshiqo and surrounding areas.

Ntshiqo alone has approximately 400 homesteads, most of whom have homestead gardens, as well as 68 one-hectare fields, of which 54 were planted with government subsidies in 2015/2016. This means that it is difficult to provide individual extension support to homestead farmers and field crop producers.

The primary mechanism through which extension and input support is provided to farmers is through government-funded programmes, which the extension services oversee. Therefore they mainly provide extension support for large scale cropping programmes. The following support programmes occur in Ntshiqo

The Eastern Cape Livestock Production Improvement Scheme

The livestock improvement programme is funded by the Department and is being implemented in partnership with the National Emerging Red Meat Producers Organisation (NERPO - Cattle) and the National Woolgrowers Association (NWGA - Sheep). The purpose of the scheme is to "promote sustainable and profitable livestock production **within resource potential**[6]". It is part of the national conservation programme and it is targeted at encouraging sustainable utilisation of natural resources" (Nkwinti, 2005, p1). The purpose of the project is to supply improved breeding bulls to farmers and to encourage the use of adapted animals by Eastern Cape farmers. The scheme requires farmers to organize themselves into management forums with a constitution and business plan.

- **Cattle** - The cattle component of the livestock improvement programme involves the provision of bulls of the Bonsmara and Nguni breed types to improve livestock. Farmers are expected to make an annual contribution to the fund of R1 000 per bull. These funds are used as a form of deposit or surety to ensure that funds are available to treat the animal should any illness or injuries occur.
- **Sheep** - The sheep component of the livestock improvement programme involves the provision of superior Dohne Merino rams to improve the gene pool and enhance the quality of the wool. NWGA provides rams to farmers through Boere Korporasie Beperk (BKB) who have a presence in the community and purchase wool from farmers in Ntshiqo. Farmers are expected to make an annual contribution to the fund of R400 per ram that is provided to them. Initially farmers have to swap their own rams with breeding rams (one-for-one) provided by the project. Thereafter, farmers are expected to replace the breeding rams provided to them on a regular basis (every two to three years). In addition to the genetic improvement of sheep, training is also provided in shearing, animal health and nutrition. Communal marketing of wool also occurs, where BKB buys bulk wool and the income generated from wool sales is distributed to wool producers on a *pro-rata* basis, based on the weight of wool supplied by each farmer.

[6] Own emphasis

Cropping support programmes

The primary programme of the ECDRDAR in relation to cropping is the Food Security Programme, which has two components, the cropping programme which focuses on the planting of maize crops in the fields (croplands normally 1 ha in size) and the household garden programme called the Siyazondla programme which assists in providing inputs to farmers with small household gardens (small amounts of fertiliser, vegetable seedlings and chemicals).

As far as support to field crop production is concerned, a number of support programmes have come and gone over time. The Massive Food Production Programme (MFPP) started operating in Ntshiqo in 2003, under which farmers with fields are subsidised with mechanisation and input supplies (including glyphosate tolerant maize). Initially farmers were 100% subsidised for the full cost of land preparation, planting and spraying and did not have to contribute anything financially. The following year, in 2004, the programme changed to Siyakhula Massive Food Conditional Grant Programme where farmers were required to pay a certain percentage of the total input costs, starting from 0% in the first year to 25% in the second year to 50% in the third and 75% in the fourth year. The idea behind this programme was that farmers would become financially self-sufficient at the end of the project.

These programmes which have been called by different names, all serve the same purpose and have run for a period of six years (2003-2009). In Ntshiqo the programme was eventually closed in 2009 due to farmers no longer wanting to pay into the programme. A number of reasons are attributed to the farmers no longer paying. Firstly, there were institutional challenges. Livestock owners agreed to keep livestock out of old lands that were being put back into production, however when grazing was limited, livestock owners forced farmers to harvest the maize early so that livestock could graze on the crop residues. Group dynamics between farmers themselves and within the cooperatives they were required to establish was also another problem. Poor management of finances, changes in membership and high attrition rates were common. Secondly, the quality of contracting services provided by independent contractors appointed by the Department was poor in many cases, particularly in relation to the planting of crops. This is attributed to a lack of knowledge and capacity on the part of the contractors combined with poorly maintained and poorly functioning machinery. As a result of poor contracting services, farmers obtained low yields and refused to pay the required contribution. Thirdly, farmers did not save the proceeds of crop sales to re-invest in the next growing season. As a result of these factors, the programme did not work as expected.

Following the dissolution of this programme, a new cropping programme was formed. This new programme started operating in 2013 and was called the Letsema Programme which focused on increasing food production within the Ntshiqo area and provided assistance to farmers through the Department's Food Security Programme. With this programme, the Department subsidises the farmers with 80% (R7,200) of the total cost of land preparation, planting and spraying, and the farmers pay the remaining 20% (R1,800) either from their own pockets or by taking a loan from the Eastern Cape Rural Development Agency (ECRDA) which they have to repay before the next growing season. The last year of this programme occurred in 2014/2015, where 54 ha were planted. In the year following the closure of the programme, 4 ha were planted in the fields. This suggests that that many farmers are unwilling to risk investment in crop production without subsidisation.

The Siyazondla Homestead Food Production programme, which also falls under the department's food security programme focuses on vegetable production in homestead gardens. Small homestead vegetable gardens (isitiye) up to a maximum size of 12 x 12 m are supported through this programme. The programme provides farmers with starter packs which include wheelbarrows, forks, spades, rakes and watering cans as well as production inputs such as seeds, fertiliser, seedlings and insecticides for free during the first year and provides extension support thereafter (Nongcawula, 2014). No food gardens associated with the Siyazondla programme were observed in Ntshiqo during the research period.

Local institutional and organisational arrangements for agriculture

This section discusses how people in Ntshiqo organise themselves in terms of farming operations and to access support from government-funded programmes. The chapter is divided into two sections, namely how farmers have organised themselves to take advantage of livestock support programmes and how farmers have organised themselves to take advantage of cropping support programmes.

<u>Organisation of farmers to access livestock-related support</u>

Local rules require that the livestock should only graze within the designated grazing areas of Ntshiqo. Similarly, livestock from adjacent communities should remain within their designated grazing areas. In reality, livestock from Ntshiqo are grazed in adjacent grazing areas and livestock from neighbouring communities do graze in Ntshiqo, as these rules are not effectively enforced by traditional leadership. As a result, the movement of livestock is relatively uncontrolled.

The rules for keeping livestock out of croplands are that livestock are prohibited from going into croplands before the crops are harvested. If local farmers find livestock which are not theirs in their fields or homestead gardens, they are entitled to impound the animals and fine the owners. Fines for cattle and horses are R50 and for goats and sheep are R15. Because of an absence of proper control of livestock, only fenced fields are farmed.

All farmers participate in the livestock dipping and vaccination programmes provided be the ECDRDAR. Farmers also regularly dose their sheep for internal parasites and some treat their sheep for blue tongue, pulpy kidney and false lumpy skin disease. Some farmers also provide feed supplements for their livestock in the form of protein licks, while others purchase hay.

The dosing and supplementation are however, acts of individual farmers and are dependent on having cash available to purchase these inputs. There appears to be no collective action on the part of livestock owners to formally or informally manage livestock and grazing as a whole.

Some livestock owners collectively make use of herders, but the herders are used primarily to protect livestock from stock theft.

There is no system in place to manage grazing on the grasslands that are available to Ntshiqo livestock owners. There are no burning regimes in place or any rotational resting or grazing systems. Fire is seen as a negative component for grasslands, which reduces available forage and therefore is not considered as a management tool. Fire is considered a serious matter, hence anyone caught lighting a fire regardless of the size, is taken to the traditional authority who then deals with the culprit accordingly. Due to a lack of grazing management, key components of rangeland productivity, such as vegetative ground cover, net primary production and species composition of rangelands have been negatively affected. When grazing becomes limited within Ntshiqo, some livestock owners transfer their animals to families closer to Maclear where there is higher rainfall and better grazing is available. A few farmers have collectively purchased a farm near Maclear and keep most of their livestock on this farm.

The livestock improvement programme discussed above is being implemented in Ntshiqo. In response to the programme, local farmers in Ntshiqo have established two local organisations to access the benefits of the Livestock Improvement Programme, the 'Masifuye' Project for cattle and the Ntshiqo Wool Growers Association for sheep.

The Masifuye project is also known locally as the Ntshiqo Red Meat Producers Project is a local organisation was established to access the benefits of the cattle component of the Livestock Improvement Project. This was initiated by Mr Tshabu, a local community member who is very active in securing projects for the Ntshiqo community. He is a passionate farmer and has been instrumental in bringing a number of projects to Ntshiqo, as will be shown in discussions below. The Ntshiqo community received seven Bonsmara bulls through this project, for which they paid R1 000 for each bull (a total of R7 000). If the animals become sick, the state vet has a clinic which either sends a livestock trailer to bring the animals to the Department for assessments or the state vet personally goes and assesses the bulls.

Due to the poor condition of the grassland in the grazing area and the limited available grazing due to overstocking, these bulls have not been performing well and have been relocated to a farm in Maclear that has been purchased by some livestock owners in Ntshiqo. The traditional Xhosa Nguni bulls owned by Mr Tshabu that were at Maclear have subsequently returned to Ntshiqo. They are provided to local farmers free of charge. An application has been made to the ECDRDAR to secure higher quality Nguni bulls to improve livestock in Ntshiqo, although these have not yet been provided.

The Ntshiqo Wool Growers Association is another initiative spearheaded by Mr Tshabu to secure a market for wool and to exchange their old rams for breed improvement, particularly in relation to wool quality. The farmers need to register through Mr. Tshabu to get access to a ram and bring one of their own ram for exchange purposes. The Ntshiqo Wool Growers Association has a constitution and respective office bearers but they are not functioning well. As a result, Mr Tshabu has been running most of the operations ever since the association was formed. The association is still operational to date and farmers receive new rams on an annual exchange basis.

Farmers who are part of the wool growers association shear their sheep once a year in October. The wool contribution by each farmer is weighed and recorded. The wool is collected by BKB in December/January and payment is made shortly after collection. BKB issues one cheque for the total value of wool collected and the farmers cash the cheque and split the cash on a pro rata contribution made by each farmer to the bale. In terms of the rams, BKB personally brings new rams and collects old rams from Ntshiqo. Mr Tshabu coordinates the process, records information on wool supplied, communicates with BKB and oversees payment to farmers.

<u>Organisation of farmers to access crop production support</u>

Mr Tshabu, who has also been instrumental in engaging the Department and securing programme support for farmers in Ntshiqo for crop production, motivated for the Massive Food Production Programme in Ntshiqo, which started in 2003. Mr Tshabu came to know of the project from a farmer in Mthatha through their local sheep organisation. The Massive project operated for six years (2003-2009) during which the name of the project changed quite a number of times from Massive to Letsima to CASP. Ntinga came into operation while MFPP was still operational in 2009. It was introduced to the farmers as a separate agency which also assists farmers with crop and livestock production.

In the 2013/2014 a total of 68 ha of fields were planted in Ntshiqo, 54 ha of which were planted through the Food Security Project (subsidised by Agriculture) and 14 ha that were planted with their own money. According to Mr Tshabu, there is a total of 1 300 ha available as old lands in Ntshiqo (this includes areas that are currently unfenced and used for grazing). Mr Tshabu pointed out that the Department of Agriculture had previously provided fencing materials for farmers to fence off their croplands, but they were expected to provide their own labour to install the fencing. Farmers who stood to benefit from this did not assist with fencing. Mr Tshabu attributed this to farmers being lazy and that they expected to be paid for everything, even for work that would benefit the farmers themselves in the long term. Farmers were asked if they had received any support through the Siyazondla programme. They indicated that they had not received any support through this programme.

6.1.2 Organisations providing support to agriculture in Muden

KwaZulu-Natal Department of Agriculture and Rural Development

The KwaZulu-Natal Department of Agriculture and Rural Development (KZNDARD) is the Provincial Department Responsible for agricultural support and development in KZN. There are two main sections providing support to farmers, namely the Animal Health Technicians and the Agricultural Development Technicians (ADTs) or Extension Officers (EOs), who deal with crop production and livestock production matters.

Livestock Extension support

In KZN, Animal Health Technicians (AHTs) who work under state veterinary services are responsible for animal health, including dipping (control of ticks), vaccinations for notifiable diseases and other general animal health matters. Blackquarter and Anthrax are the two notifiable diseases that livestock are vaccinated against. AHTs work closely with Livestock Production Extension officers who are responsible for matters of livestock production (e.g. grazing systems, animal husbandry and management).

The AHTs and the livestock extension officers work closely with a municipality-wide umbrella body called the Msinga Livestock Association, which represents livestock farmers and is responsible for coordinating the provision of dipping chemicals. The association receives the dip from the Department and distributes it to the dip tanks across the Municipal area through local dip tank committees. Farmers complain that there is very little support from the Department with regards to livestock health management and livestock farmer development. This has been attributed to inadequate resources to get extension officers on the ground. In the whole Msinga Municipality, there are only 4 livestock extension officers, which is insufficient given the size of the area where they are expected to provide support.

Crop production extension support

The Department has ADTs and assistant ADTs whose job it is to should provide extension support to crop and vegetable farmers. Famers reported that they have not seen extension officers visiting them for anything between one and two years. The Fabeni garden group members shared that they have seen the extension officer only once since the establishment of their garden in 2010, and were only given seeds and fertiliser on that occasion. One respondent pointed out that even when invited by a local NGO, the Farmer Support Group (FSG) to stakeholder meetings facilitated by FSG and in spite of indicating that they would visit, they do not arrive at meetings.

The only local programme that supports farmers is the mechanisation programme whereby farmers are provided with land preparation services by the Department. The process of securing tractors for land preparation requires farmers to register on a waiting list before the growing season and then services would be provided on a first-come-first-serve basis. This did not work, as farmers did not register in advance. Furthermore, these tractors are not maintained, as no service provider has been appointed to maintain the fleet. A new system for accessing tractors is now being implemented in the upcoming (2015/2016) growing season. A number of cooperatives submitted business plans to motivate to the Department to hold and operate a tractor. Successful bidders will be given the responsibility of managing a tractor to service members of that cooperative – this service will only be available to cooperative members. However, farmers at Fabeni are not aware of this process which suggests that there has been a lack of communication regarding the bidding opportunity and it is unlikely that Fabeni farmers will have access to a government funded tractor.

Non-Government Organisations providing support

Mdukatshani Rural Development Trust

Mdukatshani is an Msinga based NGO that has two main programmes for rural upliftment, namely craft and farming support. The farming support includes food security programs targeting women headed households and supporting indigenous chickens, and goats.

Their Community Animal Health Workers (CAHW) programme provides training to young volunteers in the area to support farmers in livestock health and production. The CAHW initiative is a partnership between Mdukatshani and the Department's Veterinary services. Animal health workers were trained by the Department, but are supported by Mdukatshani in carrying out their day to day activities.

The CAHW are in charge of monitoring livestock. If there are serious cases that need intervention of a technician they have a responsibility to report such cases, but for standard animal health matters they can treat livestock. The CAHW charge R2.00 per animal (goats) for injections. This has helped to alleviate the shortage of AHTs.

LIMA Rural Development Foundation

LIMA is an NGO with a national footprint and has its head office in Pietermaritzburg. LIMA is involved in a range of rural development activities, including agriculture. While there are LIMA initiatives in the Muden area, they do not currently provide support to farmers participating in the RWH&C research.

Farmer Support Group

The Farmer Support Group (FSG) is a community outreach programme of the University of KwaZulu-Natal in Pietermaritzburg. FSG conducts a variety of projects focusing on food security and sustainable agriculture. In Msinga they have established communal gardens in Mxheleni and Fabeni areas. Farmers have received training, and advice on sustainable agriculture. These farmers were also provided with fencing, garden tools and water containers. FSG also facilitates an annual Food Security/Nutrition Fair awareness event which brings together communities and organisations supporting agriculture in Msinga to emphasise the importance of growing nutritious food.

Local organisations involved in livestock management

In addition to the livestock association and dip tank committees, there is also a local committee in Fabeni known as Fabeni Camp Committee. This is a semi-formal group of livestock owners who graze livestock within the Fabeni cropping area in the winter months. To secure membership, a once-off fee of R20 is paid. There is no upper limit to membership and anyone can join. However, the current membership is not known as the record book of members has been lost.

There is also a broader Fabeni Dip tank committee that coordinates dipping days and in some cases obtains assistance with medication for sick livestock from the AHTs of the Department of Agriculture. Each diptank committee is affiliated to the Msinga (Municipality) Livestock Association which is an umbrella body established to advance smallholder livestock development and has an oversight role on dipping, auction and stock theft. The local dip tank committee elects representatives to attend the broader livestock association meetings, where they get to be informed about dipping, vaccination and auction events.

6.1.3 Discussion about provision of support to agriculture

In Ntshiqo, the ECDRDAR is the main supporter of agricultural development. The Department provides dipping services and vaccinations for notifiable diseases. Livestock improvement programmes are being implemented for cattle and sheep through the provision of improved breeding stock to improve livestock production. There is limited support for animal health management by the Department and farmers take care of their own animals as far as treatment of diseases and parasites is concerned. The Department does not assist or advise on rangeland management, which is a major concern. Considering that the Livestock Improvement Programme seeks to achieve sustainable and profitable production within resource potential, it is critical the improved rangeland management is considered. This is currently not the case. Genetic improvement of livestock will have limited impact if there is insufficient nutrition for livestock.

Extension support for cropping is primarily through the government-funded food security programme. There is limited direct extension support to farmers who farm independently in fields and gardens[7]. One extension officer and one assistant extension officer is responsible for Ntshiqo and surrounding areas. In Ntshiqo alone, there are approximately 400 homesteads, making it very difficult for two extension officers to provide effective extension support to farmers. The extension officers are under resourced in terms of vehicles and other resources to provide support.

The KZNDARD, mandated to provide extension support to farmers in Muden, does not have the capacity to provide support to the farmers in the Muden area. As far as livestock are concerned, major health matters, namely dipping to prevent tick-borne diseases and vaccinations against notifiable diseases are addressed. However, support in terms of managing livestock and grazing better is sorely lacking. The establishment of the annual Msinga goat auction is a starting point for creating a market for livestock, but has yet to create a commercial mind set among livestock owners. Extension support with regards to cropping is similarly inadequate. This may explain why there are a number of NGOs active in the area and NGOs appear to be largely providing services that should be provided by the KZNDARD.

[7] 'Fields' refers to 1ha blocks in designated cropping areas that farmers make use of for maize production. 'Gardens' refer to homestead gardens, which are part of the homestead and range from 0.1 – 0.25ha in size.

The general view of farmers in Muden was that extension services are not available to them, and this is a cause for concern. Two NGOs (FSG and Mdukatshani) were recognised as visible and supporting farmers' efforts.

In the context of outscaling, it would appear that state extension services currently do not have the capacity to provide advice and support to farmers on basic agricultural matters at both research sites. Extension support currently involves farmers attending meetings with few field visits to support farmers in their fields. The Departments instead work through specific programmes (e.g. the mechanisation programme, MFPP) and do not provide general extension services to farmers. Thus, if outscaling is to be supported by the provincial Departments, it would require the introduction of RWH&C as a programme to be implemented through the District and Local offices.

The three NGOs operating in Muden that are involved in agricultural matters appear to be very active on the ground and have been invited to the various farmers' days and awareness activities conducted as part of the RWH&C. There is potential to introduce RWH&C uptake and outscaling through these organisations, however, they are to a certain extent driven by their organisational mandates and the caveats that come with the funding made available to them.

The best approach for outscaling is likely to be one of partnership between public organisations and NGOs to collectively outscale rainwater harvesting through a combination of government and grant-funded programmes. This would allow for capacity building among extension staff while also demonstrating techniques on the ground through local NGOs.

6.2 Future options for RWH&C as perceived by farmers

Interviews and FGDs were held with farmers in Ntshiqo and Muden to get a better understanding of farmers' opinions and attitudes to RWH&C in order to inform opportunities and constraints for upscaling and outscaling of RWH&C.

6.2.1 Findings from Ntshiqo, Eastern Cape

Social considerations

Importance of food production and enhancing household food security

Farmers were asked how important growing food was for them. All seven interviewees responded that growing food was very important. Reasons for this included feeding family members, food security and reducing the cost of purchasing food. Maize was highlighted as very important as it used for own consumption and also as an animal feed (mainly for chickens). Another reason given was that "growing food and working in the garden makes one feel good and gives one a purpose".

Key constraints to crop production

Farmers were asked to list the three main constraints to crop production. The results are provided in Table 6.1. This was an open ended question and consequently the answers relate to biophysical, economic and institutional factors.

Table 6.1: Constraints to crop production mentioned by 7 farmers during a FGD at Ntshiqo, Eastern Cape (May 2015)

Constraint	No of mentions
Sun and extremely high temperatures (especially in January / February)	5
Shortage of cash to buy inputs (e.g. fertiliser, herbicides, pesticides)	5
Water shortage / lack of rainfall	4
Late planting – can't access tractors in time / can't afford	2
Controlling weeds (difficult due to old age)	2
Stalk borer - can't get access to poison	1
Lack of information / knowledge (e.g. best fertilisers for our land)	1
Hail damage	1

The major constraints to production highlighted by respondents are economic (lack of cash / access to finance) and biophysical (high temperatures in January / February and lack of water / shortage of rainfall).

Age of farmers

Farmers were asked whether they thought age was a factor affecting the adoption of RWH&C. It is necessary to point out that all interviewees were older than 50 years of age and were still actively farming. The general consensus was that age in and of itself was not a factor, although older people generally find it difficult to manage their fields and get tired quickly. One respondent stated: 'Once a person is over 60 years of age they can't do RWH&C as it requires too much work'. The consensus was that as long as there is a passion for farming and people have the energy, age is not a factor. As one farmer said: 'Age is not a factor, it's more about passion and commitment; I am older than 70 but still work my garden. I love farming, it keeps us fresh knowing we are working and growing our own food'.

The lack of participation by youth in agriculture was also highlighted through observations by respondents of laziness and 'wanting easy money' used to describe the youth. The responses to this question indicate that passion, commitment and a love of farming are important factors for the adoption of RWH&C.

Institutional considerations

Extension support

The surveys sought to better understand the extent to which extension services provide support and information to farmers. One respondent indicated that they do receive extension support from the Department. Two indicated that they sometimes receive extension support from the Department, and that they sometimes receive advice on pesticides for crop problems but that this only occurs after numerous requests for assistance. Four respondents indicated that they do not receive any direct support. One of these respondents indicated that they have attended training sessions on pest control and fertilisers provided by the Department, but no direct support in their gardens or fields is provided. It was acknowledged that the Department does bring projects, but that these projects benefit only a few farmers. All respondents indicated that they would appreciate more support and that the Department could do a better job of supporting farmers directly by visiting fields and gardens. It was also indicated that most of the support provided by the Department was only for farmers participating in Departmental projects and programmes. The general tone of discussions perceived during the interview process was that the Department was not well thought of in terms of the support provided (i.e. erratic, insufficient and not addressing farmers' needs). However, it was also recognised that there is no-one else providing support to farmers in Ntshiqo.

Tenure security

Farmers were asked how secure they feel their tenure is in relation to the land that has been allocated to them. This question sought to understand if tenure arrangements affected agricultural land use decisions. All respondents indicated that they feel that the lands allocated to them are secure and there is no concern that they will lose access to this land. It is a requirement that homestead gardens and fields are not used for building homesteads, however farmers are free to plant anything they want in their croplands. As one farmer said: 'I feel very secure in land tenure – I make all my farming decisions without fear and feel free to plant anything'.

However, while farmers consider their tenure to be secure, tenure constraints do exist in terms of tenure exchange limitations, as mentioned in 2.8. For example the absence of rental markets (Aliber and Hall, 2010; Crookes and Lyne, 2003) means that farmers are unable to securely lease 'in' land that they require for production, nor lease 'out' unused land.

Cultural considerations

Farmers were asked whether or not RWH&C conflicts with any cultural practices or traditions. All farmers indicated that there were no cultural conflicts and constraints to practicing RWH&C. Winter grazing of crop residues is important for carrying livestock through winter, however, allowing livestock access can damage and destroy contours used in RWH&C, which means that farmers would need to rebuild them at some cost to themselves. Farmers were asked how this conflict could be addressed. All farmers interviewed stated that in their homestead gardens they would implement cut-and-carry systems to provide livestock with fodder from homestead gardens. It was acknowledged that this would be difficult to do in the fields. One suggested solution for the fields was to construct robust contours so that there was less chance of damage by livestock.

Economic considerations

These questions focussed on use of crop outputs, cost of land preparation and labour.

<u>Use of the maize crop within the homestead</u>

Farmers who were interviewed were asked to describe the extent to which they use their homestead maize crops for (1) own consumption, (2) for feeding livestock and (3) for sale. The responses to this question are provided in Table 6.2.

Table 6.2: Distribution of uses for homestead maize crops in Ntshiqo, Eastern Cape

Use of maize crop							
Own consumption	Most	Most	Most	Most	Least	Least	Least
Livestock feed	Remainder / leftovers	Remainder / leftovers	Remainder / leftovers	Remainder / leftovers	Most	Most	Most
Sold	None	None	None	None	None	Surplus	Sometimes

Four of the seven farmers interviewed indicated that they use their maize grain crop primarily for own consumption. Three indicated that they use most of their grain crop as animal feed. Pigs and chickens are the main recipients of feed in all cases, although some is also provided to sheep and is only given to cattle when grazing is very scarce. One respondent indicated that they sell most of their homestead garden crop, however, this person has three homestead gardens around their house, making up a larger area, which meant that there was significant surplus in good years. Those respondents who had fields (two) indicated that most of the harvest from the fields is sold. This indicates that homestead crops are used primarily for own consumption and for feeding livestock.

Land preparation

Farmers only use tractors for land preparation in their fields. In homestead gardens they either broadcast the seed and then plough it in or plough and disc and then make use of animal drawn planters to plant their crops. Some farmers feel that it is easier to use animal drawn planters in these situations as they can turn in tight spaces in small gardens, which maximises the area planted. After the farmers had seen the RWH&C demonstrations, farmers were asked what they thought the best method for land preparation for RWH&C would be. All farmers indicated that the use of tractors was preferred. Reasons provided for this was that there was a shortage of oxen and donkeys, the existing animal drawn implements that farmers had were old and did not work properly and that using a tractor, while more expensive, was much quicker and less frustrating.

Labour requirements

Weed control and planting of fields require labour. A number of questions were asked to understand labour requirements and constraints experienced by farmers, which are discussed below.

Farmers indicated that RWH&C requires more labour. Compared with simply broadcasting and ploughing in seed, farmers felt that the building of ridges and planting along contour lines required more planning and labour. Secondly, it was felt the gaps between the rows used for runoff generation require lots of weeding. An advantage of planting in rows is that herbicides can be used between the rows should farmers choose to do so and have the necessary financial resources.

Most farmers hired labour to assist with weeding and sometimes with planting. When hiring labour to weed, weeding was done for four hours (from 06:00-10:00) on consecutive days. Table 6.3 shows how labour is used and the cost thereof.

Table 6.3: Labour use by respondents in weeding gardens and fields

Garden or field?	Crop stage	No of people	No of days	Hours / day	Payment (Rands)	Rate/day (8hr day)	Total Cost (R)
Garden	Knee height	3	3	4	40	80	360
Garden	Knee height	3	5	4	40	80	600
Field	Knee height	10	10	4	40	80	4000
Garden	Knee height and shoulder height	4 (children)	2	4	Sweets and chips	N/A	N/A
Garden	Knee height	2	5	4	50	100	500
Garden (large)	Knee height	4	5	4	50	100	1000

Homestead gardeners usually only weed once, when the plant is at knee height, and spend anything from R360 to R1 000, depending on the size of the garden. One respondent who had a field indicated that he spends R4 000 on labour for weeding. Farmers indicated that if family members, particularly younger family members, were asked to weed, they would expect the same payment that a hired labourer would receive.

Observations on the cost of labour against the benefits of RWH&C

Farmers stated that it would be worthwhile to invest in the extra labour required. The primary reason for this is that farmers have observed the improved yields associated with RWH&C in their neighbours' gardens. One respondent indicated that it was certainly worth the extra labour, but expressed concern that they would not have the money to pay for the extra labour and would not be able to do this on their own. Observations during the demonstrations were that farmers did not weed the RWH&C demonstrations, to the extent that the research team was forced to employ local people to assist with weeding the demonstrations.

Use of herbicides

Herbicides, when applied properly, can reduce the cost of labour associated with weeding. Farmers felt that it would be worthwhile to make use of herbicides to reduce the labour burden. However, proper training and provision of safety equipment would be required. There seems to be limited knowledge on the correct handling and use of herbicides. One respondent when asked about herbicides brought out a container of pesticide that had been given to her as a prize by the ECDRDAR for having grown the best vegetables. She had no idea what it was or what it should be used for. It is this kind of lack of knowledge that is a concern when encouraging farmers to use herbicides and pesticides. Proper training would be required before providing herbicides to farmers.

Farmer perceptions on the value of RWH&C

At the end of the interviews it was pointed out that RWH&C requires a high initial investment (land preparation, change of systems, etc.) and farmers were asked whether they still considered adopting RWH&C worthwhile. Responses are provided below:

- Yes I see it as worthwhile, it produces good yields and as farmers we want to achieve this so we will do all that it takes to make it work for us.
- I see RWH&C as worthwhile because I can see the difference in yield and size of cobs when comparing RWH&C to our current practice. RWH&C is better, much better.
- I see RWH&C as worthwhile and I really like it, mainly because it is very easy to remove weeds in between the rows. The rows are more defined compared to broadcasting.
- RWH&C is definitely worthwhile; we have seen the difference in MaQuvile's field. We have never seen maize like this before. We would do anything to do this RWH&C.
- I see RWH&C as very worthwhile, willing to invest in extra labour required. Best way to out-scale is to maybe subsidise farmers with fertiliser as it is very expensive, continue with demos. Eventually farmers will adopt, they love farming and if encouraged and shown, they can implement RWH&C

As can be seen from these comments, sentiments were all positive. Farmers have seen the benefits of the practice and are very keen to adopt.

Farmers' day outcomes

A farmers' field day was held in Ntshiqo on 11 June 2014 to share the concepts of RWH&C and to allow farmers participating in the trial to share their experiences. FGDs were held with participants at the field day and each participant at the field day was interviewed to understand what they considered to be the main opportunities and constraints.

Respondents overwhelmingly considered improved yield and maize production as the main advantage. This is to be expected as improved yield is a priority for farmers. In addition farmers observed at the field day that the cobs in the RWH&C treatment were larger, there were more cobs per plant and that the plants were larger, when compared with the control (traditional cultivation practices). Farmers also recognised the difference that the RWH&C contours made in terms of reducing runoff and maintaining soil moisture where crops were grown. The contribution of ley crops (vetch and oats) for winter fodder was also acknowledged. Perceptions of participants are summarised in Table 6.4.

Table 6.4: Farmers day participants' perceptions of advantages of RWH&C adoption at Ntshiqo, Eastern Cape (May 2015)

Based on what you have seen today, what are the main reasons for you to consider rainwater harvesting? (i.e. what do you see as the biggest advantage of adoption)	**No. of mentions**
Maize performed better under RWH&C - significant yield increases, bigger cob size	14
Contours make a big difference, holding the water in the soil for longer	6
Using ley crops (oats and vetch) is a big advantage for winter grazing for livestock	3
Prevents soil erosion	1
Maintains constant yields, even under dry conditions	1
The system does not require lots of finance and makes use of locally available equipment	1
Total	26

Specific comments provided by farmers in relation to advantages are provided below:

'I have seen for myself that there is a huge difference in yield when comparing the RWH&C system to our conventional way of planting. The RWH&C system produces bigger and better cobs'

'The RWH&C system does not only benefit me but my livestock also benefit from the oats and vetch intercropping. The system makes use of available resources more than finance, which is an advantage'

'The fact that the system prevents soil erosion, which is a major challenge here in the Eastern Cape. The maize performance in RWH&C is outstanding and the yields from the RWH&C are also very high'

When asked about challenges to adoption, more than half the responses to this question were that there was no major challenge to adoption (Table 6.5). Some respondents indicated that economic factors were a consideration. In particular, tractor hire costs and higher initial costs were considered to be a challenge. While most homestead gardeners and all field crop farmers make use of tractors for land preparation and planting, the additional work required by the tractor to build the ridges is an additional cost to farmers, many of whom have extremely limited financial resources.

Table 6.5: Farmers' day participants' perceptions of the challenges to RWH&C adoption at Ntshiqo, Eastern Cape

Based on what you have seen today, what would be the main reason for not using rainwater harvesting (i.e. what do you see as the biggest challenge to adoption)	No. of mentions
I don't see any reason not to adopt / no major challenge	12
Lack of financial resources (e.g. tractor hire) / cost of implementing system / high initial investment	3
Access to machinery for land preparation	1
We are no longer used to physically removing weeds, we now use herbicides	1
I am willing to pay whatever it takes. To me yield is the most important	1
Old age is a constraint - I can't work in the garden like I used to	1
If your soil is very hard, it will be difficult to form contours	1
The biggest challenge is planting by hand (referring to fields)	1
Total	21

On the face of then, it would appear that farmers see benefit in applying RWH&C in their homestead gardens and fields and that there is interest in applying the system in homestead gardens and fields. It should however be borne in mind, that some respondents may have answered in this manner to secure participation in the project to access land preparation and inputs at no cost. It was clearly explained to farmers, however, that this is a demonstration and research project and that farmers who wished to adopt RWH&C would be shown how to apply the system, but would not be provided with inputs or assisted with land preparation. Some specific comments are summarised below.

'I am unemployed and would therefore struggle with financial resources required for the RWH&C, but despite that I am willing to adopt this technique because it is worth it'

'The only biggest challenge I see with the RWH&C is access to finance for ploughing and not having inputs such as fertiliser, seeds etc.'

'No major challenge for me, I love the contours and I will never go back to planting the old conventional way ever again'

In addition to the survey, FGDs were also conducted at the farmers' day to better understand the value farmers saw in RWH&C, whether they thought their land was suitable for RWH&C, willingness to change to RWH&C, challenges to implementation and how adoption should be supported. The outcomes are summarised in Table 6.6.

Table 6.6: Responses from focus group discussions about adopting RWH&C at Ntshiqo, Eastern Cape

Guiding questions	Responses
Do you see value in the RWH&C?	All participants indicated that they saw benefit.
What value in particular do you see?	Maize plants are bigger with RWH&C.
	Size of cobs is higher compared with cobs from conventional plot.
	Plants are bigger in RWH&C.
	Need to commit to proper land preparation and weeding to get good results.
	Vetch and oats are an important benefit (only available food at this time of the year for livestock).
	More interested in getting seed for vetch and oats (available at coop in Maclear).
	Consistent yields are obtainable from the RWH&C.
	Height of the plant is taller.
	The stalks are not the same as the ones on our traditional maize, the RWH&C stalks are bigger and they look better.
	Since the contours seem to hold water in the soil for longer, we see great benefit for our plants. They are able to grow bigger and they look better.
Do you think your land is suitable for RWH&C? Why?	Mrs Sokhombela, Mrs Quvile, and Mrs Nkompela: Yes, because our soil was tested before the trials were implemented on our fields.
	The other farmers say they don't know because their soils have not been tested, but in terms of size all farmers agree that their lands/gardens are all suitable for RWH&C since most of their gardens are the same size as Mrs Quvile's field, if not bigger.
Are you considering changing your current practices to include RWH&C? Why?	We are willing to change to RWH&C as we can see the benefits of RWH&C. We have also noticed that RWH&C crops get sufficient fertiliser individually (referring to micro-dosing along rows) unlike when we broadcast the fertiliser.
	We can also see that the water retained in the contours has made a huge difference to the size of the maize crops.
	We see great value in the contours, they are important and helpful.
	We are willing to change to RWH&C as we can see the benefits. We have also noticed that RWH&C crops get sufficient fertiliser individually unlike when we broadcast the fertiliser.
What do you see as the biggest challenge to implementation?	Tractors and machinery are not likely to be a problem, but in gardens extra labour for planting is a problem. Possible solution could be to use an animal drawn planter; it works much better than a tractor in small field/garden.

Guiding questions	Responses
	Obtaining jab planters (Mr Nongcawula- Kokstad).
	Generally no other challenges for application in gardens.
	Big fields problem: would need to change planting system, farmers should consider fields due to yield benefits.
	Challenge with big fields is that more resources are required - cost of machinery etc.
Who should be supporting the out-scaling of RWH&C? What support is required (technical /machinery /training)?	The government should be providing assistance in the form of: machinery, extension support, RWH&C should be included in Department programmes and policies.
	Distribution of information about RWH&C to more people in different places through demonstrations, farmer to farmer trainings and workshops/ field days like this one.
	Department of Agriculture: Tractors.
	Municipality: Finance/funds.
	ECRDA: Training (through GreenSA).
	Farmers who are currently under the project must be used as mentors to out scale project to the whole of Mhlontlo municipality.

In terms of value and benefits that farmers saw, responses were similar to those of the individual questionnaires, namely higher yields, higher production, better soil moisture and the benefits of the vetch / oats combination for livestock fodder.

Regarding suitability of land, farmers felt that their land was suitable for RWH&C but indicated that their soils had not been tested. This indicates that farmers require more information regarding the biophysical parameters for RWH&C. Soil surveys conducted at the research sites found that all soils were deep (>1.5m). Considering the general topography of the area (rolling hills, gentle to moderate slopes), it is likely that most soils in Ntshiqo where farmers are growing crops are deep and therefore suited to RWH&C.

Regarding changing to RWH&C farmers indicated that they were all considering changing to RWH&C. Challenges to implementation focussed on costs and scale. Participants highlighted the higher labour requirement (and cost) associated with weeding and planting. Two solutions to this were identified, firstly, the use of animal drawn planters which can increase efficiency in homestead gardens as they turn much more easily in smaller gardens compared with tractor drawn planters. The second solution was to make use of jab planters (hand held planters) to reduce labour requirements and costs. In bigger fields, the additional land preparation costs associated with establishing contours was highlighted as a challenge, but that farmers should consider the yield benefits.

In terms of how outscaling should be supported, government support was considered important. It was highlighted that ECDRDAR should assist farmers with the provision of machinery, extension support and that RWH&C should be included in government's policies and programmes to support farmers in the E Cape. Training and demonstrations, such the demonstration trials currently being implemented in Ntshiqo were also considered important. Farmer to farmer sharing and using farmers participating in the project as mentors was also highlighted.

6.2.2 Findings from Muden, KwaZulu-Natal

The feedback gathered through individual interviews and FGDs regarding factors affecting adoption of the RWH&C practices is provided below.

Outcomes of individual interviews

Importance of food production and enhancing household food security

Farmers were asked how important growing food was for them. All responded that growing food is very important, as it helps meet the consumption needs of the household and food security, and reduce costs associated with dependence on purchasing food. Most farmers grow white maize for consumption. Farmers indicated that because growing food is important, and they often have poor yields, they need to be capacitated to identify constraints, opportunities and develop innovative practices.

Key constraints to crop production

The farmers highlighted the following constraints as key to crop production:

- Shortage of water.
- Poor fencing.
- Pests and diseases.
- Poor soils.

With assistance from external organisations (mainly NGOs), farmers have taken some steps to solve production problems in their farming systems. The major constraint highlighted by farmers is a lack of rainfall, particularly in the most critical stages of the crops growing season (tasselling in the case of maize, the staple crop).

Use of crop and marketing

Farmers were asked to share how they distribute crops according to home consumption and selling. All farmers responded that household consumption took priority as farmers are more concerned with feeding their families first. In addition to this, there is insufficient produce to sell due to the limited production scale. Farmers indicated that they did sell under the following conditions. Firstly those involved with communal gardens with access to water and those in irrigation schemes who could achieve better yields would sell produce. Secondly, when there is good rains and a good maize yield, farmers often sell 'green mealies' for cash and set aside a portion of their crop to dry and store for home consumption. In some cases, farmers who achieve good yields of dry maize grain will take it to the milling stations in Tugela Ferry approximately 15 km away (since there are no local or mobile milling stations available).

Marketing of livestock

This is an important aspect to understand because it impacts on the extent to which livestock owners are likely to invest in cropping practices aimed at improving fodder production. Some informal marketing of livestock occurs between farmers and sometimes with outside parties. These transactions are usually conducted on dipping days as livestock and their owners are in one place. There is also a cattle auction, but this does not do well because farmers are reluctant to sell livestock through auctions, as they do not consider their livestock to be commodities to be traded. Consequently most marketing is on a one-to-one basis.

In addition to this, an annual goat auction has been established. This is a joint initiative of the Department of Rural Development and Land Reform and Mdukatshani, a local NGO. This has proven to be useful to farmers wanting to sell their livestock. However, farmers are Fabeni do not really understand how it operates in relation to commissions, fees and timing for selling their livestock. While information about the auctions is provided to persons who represent the local dip tank committees at the Msinga Livestock Association meetings, this information is not effectively disseminated to livestock farmers in Fabeni.

Mr Thabede, a livestock production technician in Msinga also noted that the auction has it fair share of challenges, including:

- Farmer mobilisation and lack of willingness to sell by farmers. While the Department tries to create awareness, through the livestock association, this has not been very effective so far.
- Infrastructure for the auctions needs to be improved (the loading banks for loading cattle and the repairing of fences and kraals at the auction site).
- A number of cattle auctions had to be cancelled due to insufficient number of animals to be sold. Only one cattle auction has been held successfully in 2014 with 147 animals sold.
- Transportation of animals to the auction is also a challenge. Some animals do not get to the auction because the transport is not available to collect animals from all farmers. The livestock association has limited resources to hire transport.

Labour requirements

The general view from respondents was that most households make use of family members for labour. In some cases farmers may request neighbours to assist and will either assist in-kind when the neighbour's fields need weeding, or by sharing a portion of the harvest with those who have assisted. Farmers do not employ labourers and rely mainly on family members to assist.

When asked if they felt that RWH&C required more labour, all respondents indicated that it did indeed need more labour. The normal planting method of broadcasting and then ploughing seeds into the soil was considered to be less labour intensive. With the big gaps between the rows used for RWH&C, full canopy is never achieved, meaning that weeding is necessary throughout the growing season. Using the broadcast method, little weeding is required once the plants have grown sufficiently. Young respondents in particular indicated that they do not see themselves taking it forward due to its labour intensity.

Economic considerations

From an economic perspective, farmers were asked if the costs associated with RWH&C were acceptable. The response was that farmers would need to have sufficient financial resources to cover the additional costs of hiring a tractor or donkey drawn ploughs to plough and build the contour ridges. One farmer who owns a tractor mentioned that with RWH&C he would need to charge more than the usual fee if building ridges is required. He did not think that farmers would be willing to pay extra cost. A young respondent interviewed shared the same sentiment, saying that he does not think his family would be prepared to spend the little money that they had available for establishing contours required for this technique of RWH&C.

Current farming practices for dryland production in Muden rely on low external inputs. Land preparation is still often done using donkey drawn implements. The donkeys are shared among the farmers and farmers assist each other with land preparation, which does not require a cash investment, but simply an agreement to share a portion of the crop. Kraal manure is sometimes used as a fertiliser. In some cases farmers get assistance from the KZNDARD for land preparation, but this is uncommon. Some farmers will hire tractors from local tractor owners to prepare their land and this is by far the highest cash investment into production. Given the low and variable rainfall, farmers choose a low external input to reduce risks, which is a good economic strategy under these conditions. Thus they would be unlikely to invest in additional cash outlays under such risky conditions. This is particularly relevant given the poor rainfall that has occurred in the two growing seasons that research has been conducted at Muden. As one farmer said: 'when we live in such a dry place, there is no guarantee of a return on our investment in terms of increased yield – our crops failed and rainwater harvesting didn't help'. Given that farmers are resource poor and still have to invest in other farming inputs (e.g. seed), and in the context of the current drought, the additional costs of RWH&C would probably inhibit wider adoption.

Tillage practices

The preferred method to till the land is tractors. Farmers were asked if tractors were easily accessible to them. The responses were that there are some farmers with tractors, but not enough to meet the demand during the farming season. This in turn becomes a setback and results in late planting which affects crop growth. Government tractors rarely come to assist farmers, and when they do come they only help a few farmers, because they will indicate that there are terms and conditions, for example being a member of a farmers' association. The contractors and extension officers often say there is not enough money to keep the tractors going (e.g. fuel and maintenance). Farmers were asked what they thought is the ideal method for RWH&C land preparation. They all indicated that tractor is the most preferred method, reason being that tractor use is quickest. The lack of access to tractors is thus a limitation to the adoption of the RWH&C practices.

Cultural considerations

When the respondents were asked whether RWH&C conflicted with traditional practices, the main response was that there were no cultural impediments, but that the only way to reduce costs for land preparation for RWH&C was to keep livestock out of the cropping areas in winter to protect the contours and thus extend their life. Excluding cattle from cropping lands was considered unacceptable as the croplands are an important source of winter fodder. Farmers were asked if they would consider cut-and-carry systems for the maize stover, but farmers indicated that the labour required and the distance that the stover would need to be carried would be too far.

Perceived benefits of RWH&C

When asked if they perceived any benefits from RWH&C in terms of improved crop and livestock production, farmers indicated that they want to achieve better yields for family consumption and possibly for sale. They indicated that while they could see that the RWH&C treatment looked better than the control while the crop was growing, ultimately all the crops failed. However farmers were also optimistic that the following season would bring better rains and that they would be able see the difference in yields. This did not occur, as the drought extended into the 2015/2016 season, resulting in crop failure at Fabeni, Muden, KZN.

Focus group discussions

FGDs were also conducted to give farmers an opportunity to give their collective feedback about the value of RWH&C. The discussion was attended by 17 farmers (6 males and 11 females) representing Mxheleni Women's Group, Fabeni Communal Garden Group and the Majola family garden group. Members of the local dip tank and winter grazing camp committee were also in attendance. The mix of farmers practicing farming in different land settings allowed for more in depth analysis on the adoption of RWH&C technology. A group discussion was facilitated to find out what has been identified, tested and evaluated as possible innovative and institutional challenges to smallholder agriculture in general and RWH&C specifically.

The FGD was facilitated through the application of Participatory Rural Appraisal (PRA) techniques to actively engage participants. A problem tree was used to understand general constraints in crop and livestock production, which then allowed for the specific engagement with farmers on the RWH&C trial. Farmers were asked to identify the major constraints to crop and livestock productions, and these were prioritised.

Constraints to crop production

The first exercise of the FGD was to get farmers to list and then rank the major constraints to production that they experience and what they do to address them. These were divided into crop production and livestock production constraints and are discussed below.

Shortage of water/ No rainfall (Ranking: 1)

According to farmers, 2014/2015 was the worst year of drought. This affected both crop and livestock production. There was no rain, rivers and dams were dry. There was no water for homestead garden irrigation and for livestock. This situation was worse for farmers who farm on big fields and depend solely on rainfall. Farmers have been exposed to different methods of water conservation (e.g. contours in their fields and mulching, and raised beds in homestead gardens). The following options / solutions were identified:

- Farmers shared that RWH&C with contours needs to be backed up with tanks for water storage (although this is not possible for field crop production, given the distance of the fields from the homestead).
- In Mxheleni some of the communal garden group members have started to build contour ridges using stones in their individually demarcated vegetable plots for the purpose of harvesting water. This is because they did see benefits in the stone contour bunds that were established in their field cropping area.
- In Fabeni some farmers were planting on raised beds and applying a layer of mulch for moisture conservation in their homestead gardens.
- Farmers acknowledged that RWH&C with contours required more labour and was expensive, but that it did contribute to increased crop yield and more stover for livestock. However, 2015 was a most difficult year for farmers, with no yield from the demonstrations at Fabeni although at early crop growth stages, the maize crop in the RWH&C treatment was looking good.
- RWH&C, coupled with the installation of jojo tanks at household level and some communal gardens should be considered.
- Since the area is prone to severe drought, farmers highlighted that drought resistant OPV maize seeds are the most preferred. They also felt that fodder crops that could also be used for livestock feed should be planted.

Poor fencing (Ranking: 2)

Farmers acknowledged that they have been supported with fencing to fence off their gardens and grazing camps by the KZNDARD, but over time, the fences get older are not strong enough to keep livestock away from the croplands. This may also be a result of a lack of maintenance of the fences by farmers.

Pests and diseases including birds (Ranking: 3)

The prevalent pests and diseases affecting crops were identified as follows: termites, aphids, birds and seed weevils. Farmers have been introduced to agro ecological and environmentally friendly solutions of managing them such as chilly/garlic spray, wood and aloe. They cannot afford to buy chemicals, and they have no knowledge of their application. The organic remedies they have been using are working, but it was highlighted that as a farmer you need to be consistent in application before the crop gets infested by pests.

Low soil fertility (Ranking: 4)

Farmers also indicated that low soil fertility might affect yields. Farmers indicated that they had attended sessions on composting, kraal manure, liquid manure (tea) and soil testing. These methods are mostly applied in household and communal vegetable gardens. Soil fertility was not identified as a major constraint.

Labour (Ranking: 5)

A shortage of labour was also highlighted. With urban migration and young people unwilling to work in the fields, weeding was a challenge. Also the removal of rocks and stones from fields was hard work for older people. However, farmers in Muden did not consider this to be an insurmountable challenge as famers shared the weeding load among family members and neighbours with the understanding that they would share in the benefits of the harvest (a practice known locally as 'isithembu')

Livestock production constraints

Farmers identified three major livestock production constraints, which are discussed below.

Shortage of fodder for grazing during the dry winter season (Ranking: 1)

Grazing land is available but it is not properly managed and controlled and is not fenced off. Farmers related the lessons learnt during the cross-visit to Ntshiqo (the Eastern Cape research site), specifically the rotational resting experiment, and were interested in testing it. They indicated that they do have structures in place (e.g. traditional authority) which is the primary custodian of land. In collaboration with livestock associations there is potential for the development of a more sustainable grazing management system.

Water sources drying out (Ranking: 2)

Shortage of water for livestock has been an ongoing challenge for farmers. Animals rely on streams and rivers to access drinking water but they dry up during droughts. This is continuously raised even during Livestock Association meetings to appeal for support from the Department of Agriculture and the Municipality, requesting the construction of small dams, but there has been no response.

Diseases (Ranking: 3)

Farmers mentioned that there is a disease affecting goats which they call water in the brain, this is detected when the animal is slaughtered but they can also identify symptoms, such as the goat being restless and not want to eat. This is likely due to internal parasites (tapeworm cysts in the brain).

Tenure security

Farmers were asked how secure they feel their tenure is in relation to the land allocated to them. None of the participants raised concern around tenure. They seemed to be satisfied with land allocations and rules that have been put in place by the traditional authority around land tenure. Follow up questions were asked with regards to land leasing. The respondents outlined that the process is clear and being followed by those who want to lease land to increase their farming scale.

Some farmers felt that the leasing of land is not properly regulated and that it has its weaknesses in the sense that it does not specify the number of years for leasing. The lessor and lessee simply agree verbally with nothing in writing to specify what the lease period will be. Sometimes a lessor becomes greedy when seeing the yield and will want to take back the land with no plan to use it. This area needs to be strengthened because it limits farmers' ability to expand production areas, and the traditional authority needs to enforce and regulate the land leasing process because they are the custodians of the land.

Support provided to farmers

The question was asked to better understand the extent to which government extension services and other organisations provide support to farmers. Farmers identified a number of organisations that they believe can support their farming efforts for example Departments of Agriculture, Social Development and Health. Some of these government organisations were supporting farmers, but farmers believe they require more support. Farmers were also asked what steps they have taken to engage with the Department of Agriculture. The responses were that FSG had been facilitating multi-stakeholder meetings to bring government agencies and farmers together, however, there has been a decline in participation by these government organisations and they no longer attend meetings. Thus the multi-stakeholder meetings actually consist of two stakeholder groups, the famers and the NGOs. Members of Fabeni communal garden indicated they have not seen the extension officer for over a year. The general view of farmers was that an extension service is not available to them, and this is a cause for concern. Two NGOs (FSG and Mdukatshani) were recognised as being visible and supporting farmers' efforts.

6.2.3 Discussion about farmers' perceptions about RWH&C

Growing food was highlighted as very important for farmers in both Muden and Ntshiqo. High summer temperatures and lack of rainfall were noted as important constraints to production by farmers. The other major constraint raised by farmers was lack of money to purchase inputs. Other challenges mentioned by some farmers included controlling of weeds, which is a difficult process for the mainly older farmers in Ntshiqo, lack of information and knowledge of agriculture, pests and hail damage.

The results from the interviews, FGDs and farmers' days suggest that farmers have acquired knowledge on the importance of water conservation, using contours and other practices such as planting in raised beds and mulching. They acknowledged that RWH&C requires high initial investment for land preparation and planning.

2014/2015 was very disappointing with crop failure occurring at both sites in Muden (Mxheleni and Fabeni) due to drought. The Mxheleni group members maintained that had it not been for drought they would have achieved a better yield in the RWH&C treatment compared with the control. The crop was looking good in the early growing stages. Mrs Ngqulunga, chairperson of the group, said 'it is very unfortunate that we cannot control the climate'. The members of Mxheleni group were determined to continue with RWH&C in their communal plots as well as individual plots.

Age is often mentioned as factor affecting adoption of new technologies and that younger people are more likely to adopt new technologies than older people (e.g. Xue-Feng et al., 2007; Badisa, 2011). Farmers in Ntshiqo felt that age was not a factor. It is unlikely that youth will adopt RWH&C given their reluctance to engage in homestead and field crop production. It is likely that the importance of growing food will be a greater driver of adoption than age. A similar sentiment was expressed at Muden.

From an institutional perspective, tenure security does not seem to be a factor influencing adoption of RWH&C at either site. Extension support is a challenge, as highlighted earlier. Limited extension support is provided to farmers by the provincial departments and extension officers are not highly motivated to support farmers, except through government-funded programmes. The project team has actively involved the local extension officers and there seems to be some interest in the project. However without a formal government-funded programme, it is unlikely that there will be significant support for RWH&C from the Department.

Economic considerations highlighted that farmers prefer to make use of tractors and that to implement RWH&C would be more costly than normal land preparation due to the extra work associated with the construction of contour ridges. Farmers also perceived RWH&C to have higher labour requirements, particularly in terms of controlling weeds in the spaces between the maize rows for runoff generation. Most farmers interviewed employ labour to assist with weeding, so farmers feel that there will be greater cost burden associated with RWH&C. One option to reduce this cost is to make use of herbicides to control weeds. However, many farmers know little about the correct handling and application of herbicides and would require training on the proper use of herbicides.

Even in the face of higher costs, results from all interviews, questionnaires and FGDs at the farmers' day revealed that farmers perceived the extra benefits associated with RWH&C to be greater than the perceived extra costs. Overall there were positive sentiments in relation to RWH&C and a lot of interest in adopting the technology.

Recommendations provided by farmers for increasing adoption indicate that outscaling initiatives should focus on influencing government policy and programme development at municipal, provincial and national scale. Building capacity within the Department to assist farmers to establish RWH&C is also important. Finally, on-going demonstrations, training and support from the project is also necessary to enhance upscaling and outscaling.

Given the importance of growing food highlighted by farmers and the fact that water is a production constraint, RWH&C can deliver real benefits to farmers in Ntshiqo and Muden, which bodes well for out-scaling of field crop production with RWH&C.

6.3 Requirements for outscaling of RWH&C

In this section, the requirements for outscaling of RWH&C for increased crop and livestock water productivity are considered. While it was a research objective of this project to test outscaling of RWH&C, this was not achieved. The reasons for this were that firstly, RWH&C could not be tested at field scale, but only at homestead garden scale. This was because farmers who are growing crops at field scale in Ntshiqo were doing so through the government subsidised massification programmes, which had set management practices and did not allow for the integration of RWH&C practices. In 2014/2015, 54 fields were planted to maize with massification subsidies. In 2015/2016, when the massification subsidies were not provided, only two fields were planted to maize, highlighting that farmers were dependent on the subsidy to grow maize at field scale. A second factor was the drought in Muden, which resulted in a number of complete crop failures at the two research sites, thus negatively impacting on the possibility of outscaling the techniques.

Consequently, a review of the literature and engagements with local stakeholders who have participated in the research was used to infer what the requirements for outscaling would be. As indicated earlier, RWH&C was being introduced in a context where there is increasing abandonment of arable fields, with more focus being on food production in homestead gardens. In addition, it was noted that low and erratic rainfall were impacting on both crop and livestock production systems. Furthermore, there was a lack of support to agriculture in the form of effective extension support to farmers which is compounded by financial constraints faced by farmers. It should be borne in mind that farmers' perceptions might very well have been skewed by the ongoing drought in KZN as well as the recent drought conditions in the Eastern Cape.

Based on the research findings, the following are the key challenges and opportunities faced by farmers who participated in the research. The main challenges associated with applying RWH&C are listed below.

- **Main constraints to food production:** The top constraint for all farmers was drought and lack of water. Ntshiqo farmers highlighted shortage of cash to buy inputs, while Muden farmers found pests, disease and poor soils to also be constraints to production.
- **Weeding:** The large gaps (1-2 m) between RWH&C crop rows mean that more labour is required for weeding, when compared with current practices of hand broadcasting seed, which requires less labour when weeding. This was highlighted as the greatest challenge to the adoption of RWH&C.

- **Extension support:** Farmers indicated that extension support was lacking. More extension support to farmers is required.
- **Cultural constraints:** While farmers did not identify specific cultural constraints, the use of crop stover as a winter feed for livestock means that contour ridges are damaged through trampling. This increases the land preparation requirements as contours have to be rebuilt on an annual basis. Cut and carry systems for feeding stover to livestock were not considered acceptable to farmers due to the high labour requirements associated with this.
- **Land preparation costs:** Farmers make use of tractors for land preparation. These are substantial costs for resource-poor farmers and the additional cost of building contour ridges is problematic.

It should be noted that the constraints referred to above relate to production within homestead gardens. While literature and observations through this project suggest there is a movement away from fields towards homestead gardens, fields have an important role in increasing productivity. Key challenges in relation to field production are the lack of a rental market for the exchange of land, risks of cattle damage, theft and a shortage of fencing. The fact that farmers tend to grow crops in the field only when there are subsidies available is also relevant – any intervention that seeks to outscale RWH&C in fields would require addressing the challenges farmers experience in growing crops in fields. In addition, some form of subsidisation would probably be necessary to reduce the risk perceived by farmers.

Farmers considered the following to be benefits of RWH&C:

- **The importance of growing food:** Food production was considered to be very important for farmers. In Muden, food production was a critical element of household food security and all production was for the household. In the case of Ntshiqo, farmers indicated that the high cost of buying food made growing food important, although grain production was also important for feeding livestock (mainly sheep and chickens).
- **Tenure security:** farmers did not consider this to be an issue and felt that their tenure was secure.
- **Higher yields**: Farmers noted that yields were better in some RWH&C treatments, however some felt that this was offset by the higher labour requirements. Furthermore, with the drought, particularly in Muden, farmers noted that while the RWH&C treatments showed better growth initially, the lack of rainfall resulted in crops in both the treatments and the controls failing.
- **Improved soil moisture:** Farmers noted that there was higher soil moisture in the RWH&C treatments.
- **Opportunities for relay cropping:** The use of ley crops in the gaps between the maize rows were considered to be an advantage for livestock farmers in Ntshiqo.
- **Micro-dosing of fertiliser**: With maize being grown in rows, targeted applications of small amounts of fertiliser were considered to be a very cost effective use of fertiliser that improved yields, when compared with the current practice of hand broadcasting.

During the various engagements with farmers, there was substantial positive sentiment towards RWH&C. However, it is not clear whether or not farmers would continue to make use of RWH&C when the research project is completed. Should the required support be provided to farmers, there are certainly opportunities for outscaling.

6.3.1 Socio-cultural requirements for outscaling

The impact of gender

The research has shown that women remain at a disadvantage when it comes to the process of land allocation and it is more difficult for women to secure access to land. The constitutional principles of gender equality have been communicated to traditional authorities and this seems to have improved women's access to land. However men still play a dominant role in the allocation of land for women, as the application and allocation process must be facilitated by a man. Better land administration systems are being implemented, which should provide better access to land for women. The introduction of leasing systems can also facilitate the secure exchange of land between farmers. However, this is not the only constraint to adoption – access to finance for inputs is also constraining for most farmers, and this would be no different for women.

In addition, there are clear gender defined roles for farming, where weeding in particular is largely done by women in the household. With the higher weeding requirements associated with RWH&C, this responsibility would fall on women in the household. This would reduce time available for women to perform other important household-related activities as well as be an opportunity cost for other income generation options.

More equitable sharing of weeding activities within the household would be necessary to share the workload for maintaining the crops under RWH&C. Another option is the introduction of herbicides to reduce this burden, which is discussed later in the chapter.

Enforcement of traditional rules

A common theme across both sites was that of increased lawlessness, which relates both to criminal activities (e.g. theft) as well as an increasing disregard for the traditional rules governing land use and allocation. Both of these elements have an important impact on adoption of RWH&C. As North (1992) suggested, poorly functioning institutions can be a disincentive to investment and economic development, in particular where use rights are not secure.

Increasing incidence of theft, particularly livestock, means that it is challenging to implement grazing systems that improve the productivity of rangelands as livestock owners are reluctant to allow their livestock to venture far from the homestead. This places increasing pressure on nearby grazing resources as well as making the homestead garden an increasingly important source of fodder. From a livestock perspective, it will be necessary to re-establish rules for herding livestock and to introduce herding systems that are managed by herders. The rotational resting demonstration at Ntshiqo demonstrated to farmers the benefits of resting, however, once the demonstration had been completed, control of livestock movement lapsed. This was primarily due to the project employing herders for the duration of the demonstration. Livestock owners were not prepared to employ herders as this was a cost that they were unwilling to incur. This is compounded by livestock from adjacent areas not being controlled and also grazing within the Ntshiqo designated grazing area. Implementation of grazing systems requires the establishment and enforcement of grazing rules, which would need to be implemented by the traditional authority with support from the local Departments of Agriculture and with buy-in from livestock owners.

Theft of crops is also a challenge. Along with the lack of control of livestock entering cropping fields, these two factors are largely responsible for the withdrawal of crop production in fields and the intensification of production in homestead gardens. This suggests that efforts for outscaling should focus on homestead gardens as this is where farmers are most likely to invest their resources (time and money).

6.3.2 Institutional and organisational requirements

Local leadership and defined user groups

Where strong leadership with vision is applied by traditional authorities, it appears that agricultural productivity can be maintained and enhanced. This is particularly important where control of land-use decisions can be vested with small user groups with a vested interest in production. It is therefore important to support smallholder farmers who are currently farming and seek to support the emergence of institutions that can support such farmers.

Mr Tshabu in Ntshiqo has been instrumental in getting farmers involved in the various crop production programmes that are funded by the Department over the last ten years. The active role of Mr Tshabu highlights how individual action and leadership can leverage benefits for the broader community. Although Mr Tshabu does benefit personally from this in that he has a large flock of sheep and herd of cattle, and is also a planting contractor for the programme, his active pursuit of programmes has made a difference for many other people in Ntshiqo. Personal incentives for Mr Tshabu therefore lead to broader social benefits. Mr Tshabu actively attends farmers' meetings locally and in Umthatha and also engages with the Department, which profiles himself and Ntshiqo in general for better support. The identification and support of such farmers who are facilitators of change and development must be supported through partnerships with local Departments of Agriculture and local NGOs.

Extension support

Lack of effective extension support was identified as a major concern at both project sites. Better and more responsive extension services are necessary if outscaling is to be achieved. Currently extension support is based on large-scale government funded massification schemes which involve some form of subsidised production. These programmes focus mainly on cropping field and not on homestead gardens. The net result is that the cropping extension technicians are largely project managers who oversee the allocation of resources for land preparation, planting, management and harvest of crops within these defined programmes. True extension support, involving assistance with planning, production, harvesting and marketing is non-existent at the sites where the research was conducted. Exposure to new techniques of crop production is either through the private sector (e.g. GrainSA) or through NGO projects.

A compounding factor is that the massification-type projects involve the use of glyphosate tolerant crops and the application of glyphosate herbicides, which is incompatible with the homestead gardening model that involves intercropping. The massification programme in Ntshiqo has been shown to not be sustainable in its current form. In the 2013/2014 growing season, 54 ha were planted to maize in fields. In the following growing season, without massification support, only 4 ha of fields were planted to maize. This suggests that few farmers are willing to invest in field crop production without government subsidisation.

The role of NGOs and CBOs

In Ntshiqo, it was found that there were no agriculture-related NGOs operating in the area (apart from the current project being implemented by the INR on behalf of the WRC), which means that farmers were highly reliant on support from the ECDRDAR for agricultural support. In Muden, it was found that there were a number of NGOs that were active in the area, providing support to farmers for both livestock and crop production. The NGO sector currently plays an important role in supporting rural farmers and arguably is more dynamic and responsive to the needs of farmers when compared to government extension providers who operate on a fixed programmatic approach, dictated largely by the development of programmes that are not necessarily in touch with realities on the ground.

The role of the private sector

In Ntshiqo, it was found that a number of private sector initiatives were active in the area in support of agriculture. In terms of crop production, GrainSA were conducting demonstrations of new seeds varieties (glyphosate tolerant) to farmers. Where livestock are concerned, a partnership between the government, the National Woolgrowers Association and BKB has provided improved Dohne Merino rams for improved wool production. In addition, NERPO in association with the ECRDAR has supported the provision of superior bulls for improving livestock production.

Developing partnerships with the private sector is an effective means of introducing new technologies. RWH&C in cropping systems in partnership with organisations such as GrainSA brings the technology to new markets. In the case of livestock, linking better grazing management systems with livestock improvement initiatives has the potential to produce similar results.

Policies and programmes

The inclusion of RWH&C techniques into government policies and programmes is necessary for outscaling. Most rural communal farmers are exposed to extension support and new farming techniques through government programmes and this is therefore a necessary requirement for outscaling. It is recommended that RHW&C be included as a technique within a broader suite of agricultural technologies, for example, within the aegis of climate smart agriculture. Policy should seek to actively include RWH&C as a climate smart agricultural practice and strategies for climate resilience should include RWH&C.

6.3.3 Economic considerations

From an economic perspective, homestead garden food production is primarily for home consumption and in the case of Ntshiqo, also for feeding livestock. Farmers participating in the demonstrations did not meet household needs with the food grown in homestead gardens and thus still had to purchase food to meet household needs. This is juxtaposed with increasing abandonments of fields for food production. The discussion below considers costs of land preparation, labour and yields. Markets have been excluded from the discussion as farmers do not sell the crops that they grow in homestead gardens.

Cost of land preparation

The cost of land preparation for annual preparation of contour ridges was considered to be high by farmers. Where demonstrations were conducted at both Ntshiqo and Muden, the contours that had been established for the demonstrations at the beginning of the growing season had disappeared due mainly to rainfall but also as a result of livestock trampling in winter. The cost of land preparation is simply too high for resource poor farmers to re-establish contours on an annual basis. In the case of Mxheleni in Muden, stone contour ridges were established and are more permanent, and worked well over the demonstration period, suggesting that hard infrastructure is more durable. This however requires an ample supply of stones, which are not available in Ntshiqo. Minimum and no-till approaches can be used to overcome this, but contours would still need to be re-established every two to three years. Farmers would require some form of financial assistance to overcome this constraint.

Cost of labour

Many farmers reported that the high labour requirements associated with RWH&C were problematic and was compounded by a shortage of available labour. Current practices were considered to have lower labour requirements and were therefore preferable from the perspective of labour.

One option to reduce labour costs is to introduce herbicides to control weeds between the rows of crops. However, this is a challenge for a number of reasons. Firstly, this represents an additional cash outlay for farmers, which may inhibit the use of herbicides. Secondly, these are potentially dangerous chemicals and can result in serious harm if those using them are not properly trained nor have the necessary personal protective equipment. Thirdly, should farmers use glyphosate tolerant varieties, this represents a further additional cost to farmers.

Yield improvements

Farmers noted that they had observed improved yields in the RWH&C treatments, but remain to be convinced that the improved yields offset the additional weeding and land preparation costs. At Fabeni in Muden, KZN, farmers did not obtain any harvestable yields due to drought, thus their observation was that the investment in RWH&C did not provide any yield benefit. Conversely at the second KZN site, Mxheleni, for the two years where maize was harvested, yields were higher in the RWH&C treatment compared with the control. In Ntshiqo, results varied. Some of the results can be attributed to lack of weeding by farmers and in one case waterlogging. However farmers considered yields to be generally better in the RWH&C treatment. The RWH&C treatment did certainly show higher yield per plant and grain mass per cob compared with the control.

6.4 Future options for outscaling RWH&C

A proposed framework for outscaling of RWH&C is provided in Figure 6.1. The framework considers institutional and organisational arrangements to be a fundamental requirement to achieve improved LWP and CWP. Formalising and improving these arrangements create the platform for more effective technical interventions to improve management practices, achieve higher water productivity and ultimately improve livelihoods, food security and promote more resilient farming systems.

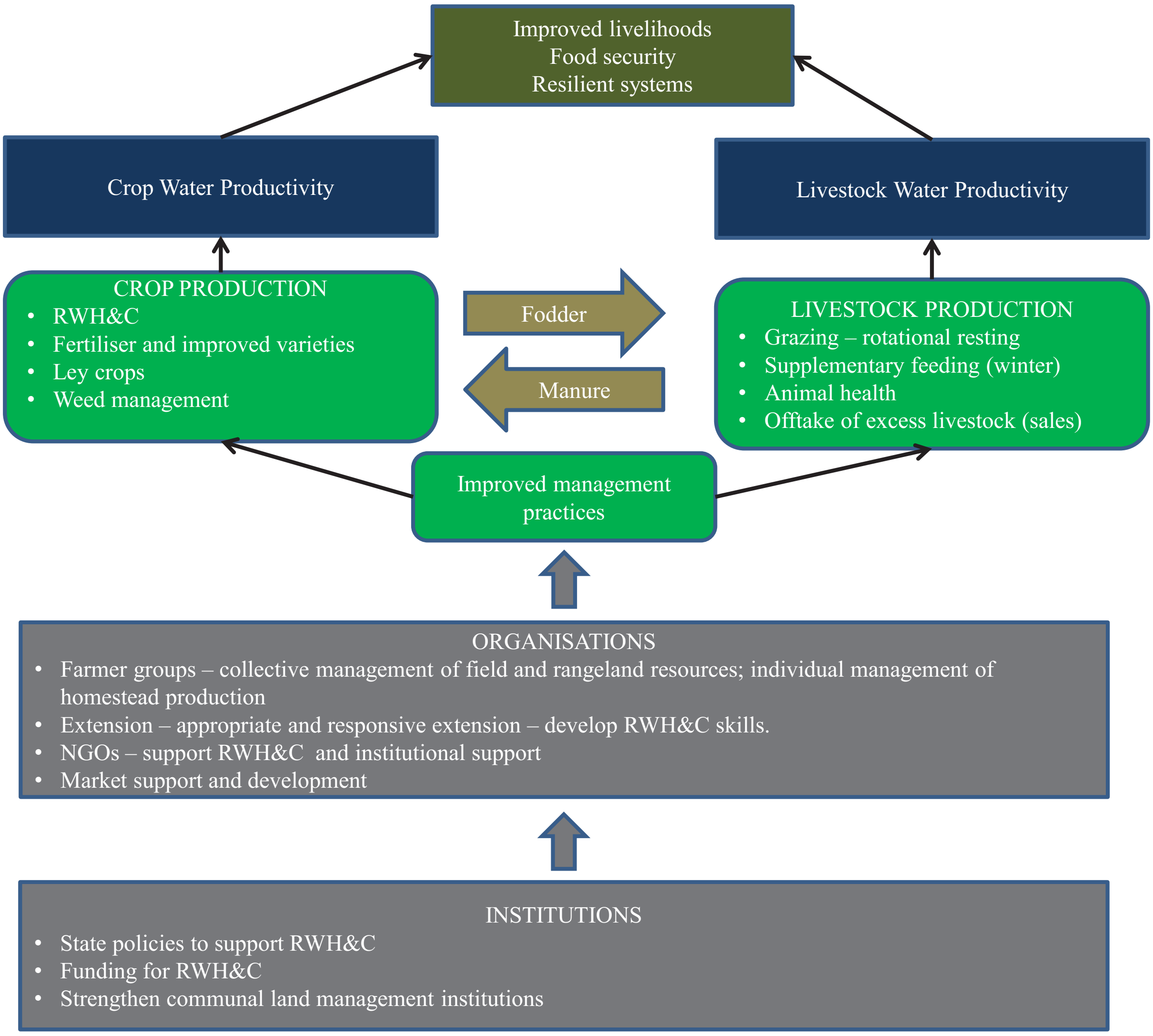


Figure 6.1: Framework for supporting outscaling of RWH&C

6.4.1 Institutions and organisational requirements for outscaling

If outscaling is to be supported by the provincial Departments of agriculture, it would require the introduction of RWH&C as a programme to be implemented through the District and Local offices. This requires the adoption of policies and support programmes to create the enabling environment for RWH&C. Given the focus on climate change, RWH&C should should be introduced within the ambit of climate smart agriculture, water smart agriculture, sustainable agriculture and food security. There is a severe shortage of extension officers, which would need to be addressed by increasing numbers and making extension support and policy in general, more accountable and responsive to farmers' needs.

Funding would be required to support the roll out of any programme supporting RWH&C. Further funding support should seek to achieve partnerships between researchers, development practitioners, NGOs and government extension services to collectively support outscaling of RWH&C with communities. This would help to address the dire lack of extension support that currently exists.

Farmer leaders, like Mr Tshabu, should be identified and supported to promote improved management techniques for both grazing and cropping in the context of RWH&C. Through him, local organisations have been established to take advantage of the sheep and cattle improvement programmes. In so doing, farmers are shearing sheep and selling wool, which is an important source of income from livestock in Ntshiqo. The Bonsmara bulls provided by the Department have been relocated as they did not perform well due to lack of adequate grazing, and have been replaced with Mr Tshabu's indigenous 'Xhosa' Nguni bulls. This highlights that grazing shortage is a problem in Ntshiqo. The policy for the livestock improvement programme (see 6.1.1) explicitly states that production improvement should occur within resource potential. However, the livestock improvement programme at Ntshiqo is not linked to any grazing or fodder management programmes, and is compounded by high stocking rates. Without better grazing management systems, the introduction of improved livestock breeds is unlikely to yield results.

In addition to funding general support for outscaling of RWH&C through programmes and partnerships, subsidising farmers to adopt should also act as incentive. The various workshops and focus group discussion revealed great interest in RWH&C, however spontaneous adoption was not observed during the research. Higher initial cost associated with land preparation was highlighted as a major constraint, suggesting that assistance with land preparation for RWH&C is required.

Private sector initiatives in partnership with government are also effective in introducing improved techniques for increasing productivity. Although these are usually focussed on using improved inputs (e.g. better rams, improved seed varieties) rather than better management of range and crop resources, they can be effective and be used to incentivise better land management through conditional support (i.e. support is only provided if certain practices are adopted, such as rotational grazing, conservation agriculture, RWH&C, etc.).

There is increasing disregard for traditional rules governing land use and allocation. This applies to traditional authorities as well as community members. Measures to strengthen communal land management institutions are a prerequisite for improved land use and management in communal areas. Strong institutions support investment and economic development. Introducing more formalised land rental systems will also encourage farmers to investing in crop production in fields. Increasing policing activities with regard to stock theft and controlling the movement of livestock in summer is necessary. This requires collaboration between traditional authorities, government and communities. Traditional authorities should work with the provincial departments of agriculture to enforce national regulations regarding conservation of natural resources and to implement better grazing management and cropping systems. Divesting land use decisions to smaller groups who are interested in production should also be supported.

Improved institutional arrangements should support farmers to collectively manage common property resources more effectively, and individuals to manage individual use rights more effectively. This combined with proper extension support and partnerships (private, public and community), should achieve higher levels of productivity.

6.4.2 Improved management practices for outscaling

There are a range of practices that can be applied in rangelands and croplands to support outscaling. This section considers selected focus areas for improving management practices for outscaling.

Outscaling of RWH&C for livestock

The focus on achieving improved LWP focuses on grazing systems, supplementary feeding, animal health and marketing.

As far as factors affecting livestock water productivity are concerned, overstocking and poor rangeland condition are major constraints. The rangelands in Ntshiqo and Muden are under intense pressure. This level of grazing is unsustainable and is likely to compromise livelihoods in the long term, despite the inherent resilience of rangelands. There are currently no grazing management systems in place in Ntshiqo or Muden, apart from the setting aside of fields and homestead gardens for winter fodder. Fire is not used as a management tool to improve rangeland production and is actively discouraged by local rules preventing fires.

The introduction of a system of regular full season's rest to improve grazing showed great benefits in Ntshiqo. However in Muden, with the ongoing drought, the combination of overstocking, continuous grazing and the recent drought has devastated cattle numbers in the area. The introduction of rotational resting is therefore suggested as a fundamental requirement for improving the water productivity of the rangelands and in turn, livestock performance. Even under conditions of high stocking rates, a rotational resting system will benefit the rangeland, by improving rangeland production and the vigour of the grasses. In the longer term, this should also improve the quality of the fodder and species composition.

Browse volume and mass availability calculations suggest that there is sufficient browse to support larger goat populations in Fabeni. This suggests that grazing and browse assessments are required to identify what measures can be taken to optimise the use of available resources, which in the case of Fabeni, would be to increase goat numbers and reduce cattle numbers.

Watering of livestock is important for LWP. This is not a prominent issue in Ntshiqo – there are reasonably good surface water resources available and livestock do not have to travel great distances to get water. It is only in extremely dry years that availability of water for livestock can be problematic. In Muden, shortage of water for livestock has been an ongoing challenge for farmers. Farmers have raised this with the Department of Agriculture and with the Msinga Municipality, requesting the construction of small dams. None have been constructed to date. However the Fabeni River still had pools of water in June 2015 despite the drought, as shown in Figure 6.2. This is not an extensive water supply and runs dry in winter following summers of low rainfall. When this source of water is depleted, farmers take their livestock to the Mooi River, which can be anything from a 3-5 km journey, depending on where the farmer is located. It is not ideal for livestock to travel such distances to reach water, especially when feed is highly limited as experienced in the prevailing drought.

Figure 6.2 The Fabeni River during June 2015

As far as addressing problems with the availability of fodder, supplementary feeding in winter can improve livestock performance. Although biomass production is low in Ntshiqo, forage is available throughout the entire year; making protein licks a viable form of supplementation. The supplementation experiment enhanced sheep production during the winter months by enabling animals to consume forage of poor quality. Making unpalatable feed acceptable and digestible can be the difference between life and death for livestock. This was important in terms of improving the forage quality under the feed management component of the LWP framework. The response from the participants was positive (LWG, 2015), which is vital for the long-term adoption of such a technical intervention, that contributes to the improvement of LWP.

To address problems with the availability of fodder, a supplementary feeding trial was initiated at Fabeni. Initially, the supplementary feeding trial was to test the impact of winter protein licks on livestock condition score. However, at the end of the winter period, there had still been no rain at Muden, and cattle continued to die. The effect of supplementary feeding could therefore not be evaluated.

In addition to protein licks, fodder crops were introduced to smallholder farmers in Ntshiqo. Growing compatible vetch and oats mixtures can be practically relevant in increasing forage productivity per unit area, digestibility, crude protein content and the intake by livestock (Assefa and Ledin, 2001). This will aid livestock in Ntshiqo to digest the poor quality veld. Vetch and oats cultivation can significantly improve the nutrient content in the diet of livestock, alleviate feed deficit, promoting and maintaining animal production during winter and positively contributing to overall LWP. It is important for farmers to observe positive influences of technical interventions, as this promotes the long-term adoption of these techniques. This was important in promoting the forage quality and feed type selection component of the LWP framework in Ntshiqo. Thus the introduction of supplementary feeding in the form of ley crops and protein supplements in winter should be supported.

Animal health has a strong bearing on productivity. Farmers generally dose and treat their own livestock. Given the high grazing pressure and poor condition of the grassland, it is likely that poor nutrition is contributing to animal health problems, as good nutrition is a prerequisite for good health. Farmers do take advantage of the dipping and vaccination services provided by the Government. Other aspects of animal health management and supplementary feeding are dealt with by the farmers themselves in Ntshiqo, while in Muden farmers purchase few inputs for their livestock. Improving animal health management, linked with proper animal nutrition, is necessary to outscale RWH&C.

Livestock owners at both sites sell livestock on an informal basis, while there is a well-established market for wool, which generates income for farmers in Ntshiqo. Outside of these informal market channels, few livestock are sold formally. Even with the introduction of the Msinga livestock auction, few farmers interviewed indicated that they had taken their goats to this market outlet. It is necessary to find ways to increase offtake of livestock through the sale of animals. This will reduce pressure on fodder resources and generate income for farmers, while enhancing LWP overall.

As far as addressing problems with the availability of fodder, the following potential solutions have been identified.

- The first identified solution is reducing livestock numbers by increasing offtake. Given that farmers mainly keep livestock for purposes other than regular income generation and the given the cultural and social value that livestock represent, it is unlikely that farmers will be willing to reduce numbers.
- The second is to implement improved grazing management systems system in the rangelands. Even in degraded grasslands, a summer rest from grazing can improve fodder

quantity in the short term and fodder quality and veld condition in the long term. Furthermore, under conditions of very high grazing pressure, rotational resting does allow for the recovery of vigour of grasslands. Coupled with this, fire should be introduced as a management tool where applicable. The resting will also aid the winter fodder bottleneck, as livestock can graze the rested area in winter. This would require organisational and institutional strengthening of the community, the traditional authority and organisations supporting agriculture and livestock production.

- The third approach is to use the RWH&C approach in croplands to increase biomass production from croplands so that there is more fodder available. Initial results from the trials show that biomass production from the maize is greater in the RWH&C treatment compared with the control. Furthermore, the inclusion of a grass / legume ley crop showed promising results in Ntshiqo.
- The supplementary feeding trial achieved significant increases in the body condition of sheep in Ntshiqo. In conjunction with improved grazing systems, this can dramatically increase livestock performance and hence livestock water productivity at both sites.
- At both sites, improvement of animal health should be addressed. While regular dipping and vaccination against notifiable diseases does occur, other animal health matters in particular dosing for internal parasites should be addressed to reduce livestock mortality and increase productivity. However this should be done in conjunction with measures to ensure adequate fodder availability throughout the year.
- In Muden, in addition to rotational resting, it is suggested that the number of goats be increased in relation to cattle numbers. There is a surplus of browse available, with signs of bush encroachment, evident further from the homesteads where browsing is infrequent. The encroachment is assisted by the absence of fire as a management tool. Increasing the number of goats would require the establishment of markets to sell surplus animals (e.g. the Msinga livestock auction). Cattle, however, remain important as an indicator of social standing and a stock of wealth and it is unlikely that farmers would be willing to reduce these numbers in the short-term.

Outscaling of RWH&C in croplands

Interviews with farmers in Ntshiqo indicated a keen interest in adopting RWH&C in croplands. Farmers have seen the benefits through the farmers' days that were held at harvest time. Farmers feel that the benefits outweigh the costs of adopting RWH&C. They do, however lack sufficient knowledge on how to apply RWH&C in their lands. In Muden, due to the drought, farmers at Fabeni experienced crop failure for all three years of the demonstrations and consequently did not see any benefits from RWH&C. In Mxheleni, tangible benefits were observed by participating farmers, in terms of higher yields.

For land preparation, farmers' current practice is to hand broadcast seed and then plough the seed in using donkey drawn or tractor drawn implements. This practice is considered to be the lowest cost option for farmers in Muden and given the risk of crop failure, it seems unlikely that farmers would invest in the extra cost of establishing contours associated with the

RWH&C technique being demonstrated, particularly given the recent drought. One option identified to reduce land preparation costs was to exclude livestock from the fields in winter to prevent them trampling and damaging contours, thus extending the life of the contours and reducing preparation costs. However this was found to be unacceptable for farmers as cropping fields are an important in providing winter fodder. When asked about cut-and-carry systems to provide fodder to livestock while protecting the contours, farmers stated that the labour and the distance to be travelled were too great. RWH&C systems can be implemented without mechanisation to reduce external costs. However, for RWH&C to be outscaled, in order to increase crop and livestock water productivity, mechanisation support in the form of subsidised land preparation would be required if the programme was to be expanded at scale.

Weed control was another challenge highlighted by farmers. At the farmer exchange visit to Ntshiqo, Muden farmers commented that weed control seemed to be a much greater challenge in Ntshiqo, when compared with Muden. Muden farmers acknowledged that current planting practices allow the maize canopy to develop quickly, which reduces the need for weeding. However, the runoff generating areas are never fully shaded, requiring more weeding than with the current practice of broadcasting. Labour for weeding is usually done by family members or with neighbours who provide the labour at no cost, but sharing in the yield at harvest time (isithembu). Few, if any cash payments are made for labour, highlighting again the preference of farmers for low external input approaches. The weeding requirement under RWH&C was found to be greater than with the current practice, and thus systems that reduce the weeding requirements would encourage upscaling and outscaling. This could include mulching or the responsible use of herbicides.

Building local capacity is another important requirement for outscaling and upscaling. Mr Tshabu has shown a passion and commitment to agriculture in Ntshiqo and is a respected community member. He is in a position to be a local source of knowledge and act as ‘institutional memory’.

Most farmers at the demonstration sites are resource poor and do not have cash or labour resources. This is a constraint to adoption. The research and demonstrations have focussed on making use of resources and equipment that farmers currently use for farming to limit excessive and unwarranted costs to farmers. Most farmers use tractors for land preparation and some make use of herbicides to control weeds. Thus adoption of RWH&C does not require great changes to resources that farmers currently use, although, as mentioned earlier, labour requirements and machinery costs for applying RWH&C are perceived to be higher by farmers.

7 CONCLUSION AND RECOMMENDATIONS

This chapter concludes the report by considering the extent to which the research objectives have been achieved, providing a summary of the research findings, reflecting on lessons learnt during the research and suggesting a way forward in terms of further research required in relation to RWH&C, as well as crop and livestock water productivity.

7.1 Achievement of research objectives

This section first considers the achievement of the project objectives contained in the project terms of reference and follows with a summary of the findings from the research.

The main objective of the research project was to:

> *Review and demonstrate rainwater harvesting and conservation methods for integrated crop and livestock production at field scale for increased crop and livestock water use productivity at two or more selected sites in communal rural areas of South Africa.*

The overall objective was achieved; RWH&C was demonstrated for integrated crop and livestock production through participatory action research with crop farmers and livestock owners in Ntshiqo, Eastern Cape and Muden, KwaZulu-Natal.

In terms of the specific objectives, achievement of the objectives is discussed below.

> *To evaluate appropriate methods of rainwater harvesting and conservation for sustainable crop and livestock production at field scale.*

An extensive review of the literature was conducted to identify appropriate methods of RWH&C, along with the advantages, disadvantages as well as the technical, social, and institutional considerations related to the choice and implementation of RWH&C techniques.

> *To determine the social, cultural, institutional and organisational status quo and dynamics influencing access to communal cropland and rangeland for up-scaling of appropriate rainwater harvesting and conservation methods.*

This objective was achieved through a review of the literature related to dynamics influencing access to communal cropland and rangeland, followed by engagement with the Ntshiqo and Mxheleni farmers to understand how access to, and use of, land works in a practical sense.

> *To determine the current levels of productivity and relationships between rain-fed field crop production and livestock production on rangeland.*

Through surveys, workshops and focus group discussions with farmers at the research sites, current levels of productivity were established. Baseline crop yields were determined and the productivity of livestock was established through a two year survey of livestock owners. Furthermore, ongoing engagements with farmers documented the relationship between crop production and livestock production.

To demonstrate appropriate rainwater harvesting and conservation techniques and practices at field and rangeland scale for improved integrated crop and livestock water use productivity.

This objective was partially achieved. Demonstrations of appropriate RWH&C techniques were conducted with five farmers in Ntshiqo and with two individual farmers and a communal farming group in Muden. Demonstrations in fields were not possible due to the decline in field crop production and a trend towards focussing food production within homestead gardens in Ntshiqo. Consequently, demonstrations were conducted at homestead gardens rather than cropping fields.

To evaluate socio-cultural, institutional-economic and biophysical requirements and opportunities for outscaling for field crop and livestock production with rainwater harvesting and conservation.

Outscaling (i.e. the expansion of the RWH&C techniques to neighbouring communities) was not achieved during the course of this project. When new techniques are introduced, it takes time for them be adopted by farmers. Learning new ways of doing things is a long-term process. The research therefore focussed on building capacity and conducting shared learning in relation to the introduction of RWH&C. Achieving outscaling is a longer term process that the project timeframes did not allow for. Recommendations for outscaling were therefore based on the results of this learning process.

7.2 Summary of findings

Through a process of participatory action research, where farmers are active participants in the research, RWH&C techniques were tested at two research sites in homestead gardens and rangelands. Conceptual frameworks for evaluating crop water productivity (CWP) and livestock water productivity (LWP) were applied to evaluate the effect of RWH&C on the productivity of homestead gardens and rangelands in Ntshiqo and Muden. Data was collected on crop production for three growing seasons to evaluate the effect of RWH&C on yield and crop water productivity. The AquaCrop model was also used to evaluate CWP at the research sites. Field research was conducted on livestock and rangelands to determine LWP and the effect of resting of rangelands on biomass production and feed quality. This was coupled with ongoing engagement and research through surveys, workshops and focus group discussions to determine baseline productivity in crop and rangelands. This approach was also applied to develop a deeper understanding of the current institutional and socio-cultural arrangements that influence access and use of land in the communal areas in question.

The research was conducted in the context of declining use and productivity of cropping fields and a reorientation towards production in homestead gardens. Findings from the literature were supported by empirical findings in the field, with a trend of declining reliance on field crop production and a focus on homestead crop production. Nevertheless, growing food remains important to farmers in Ntshiqo and Muden. Abandonment of cropping fields was found to be driven by risks of growing crops far from the homestead and declining control of livestock and theft, resulting in crop losses. Livestock continue to be considered valuable and play an important cultural, spiritual and economic role in rural areas.

7.2.1 Baseline crop and livestock productivity

The drought in Muden resulted in crop failure at the Fabeni research site in Muden, KZN, for all three growing seasons (2013/2014, 2014/2015 and 2015/2016). At the Mxheleni site in Muden, crop failure also occurred in 2014/2015 due to drought. At Ntshiqo in the Eastern Cape, rainfall was below the mean annual rainfall for all three growing seasons, but was sufficient for yields to be obtained in all three years.

Baseline crop yields in Ntshiqo, from a survey of eight farmers over two growing seasons yielded a mean yield of 1.2 $t.ha^{-1}$ in 2013/2014 and 1.6 $t.ha^{-1}$ in 2014/2015. Individual yields were highly variable, ranging from 0.3 $t.ha^{-1}$ to 3.6 $t.ha^{-1}$ in 2013/2014 and 0.6 $t.ha^{-1}$ to 2.6 $t.ha^{-1}$ in 2014/2015. Ntshiqo farmers use a large proportion of their maize as grain to feed livestock, mainly sheep and poultry, and many meet their household food requirements with cash purchases.

Baseline crop yields in Muden were determined from a survey of eight farmers conducted in 2013/2014 and 2014/2015. No yields were recorded in 2014/2015 due to the drought where farmers participating in the baseline survey either did not plant crops or had total crop failure. Only three of the surveyed farmers obtained yields in 2013/2014 and the yields obtained were 0.2, 0.6 and 0.8 $t.ha^{-1}$, substantially lower than those achieved in Ntshiqo. In contrast to Ntshiqo, few farmers used grain to feed livestock.

Livestock productivity in Ntshiqo, measured in terms of lambing and weaning percentages was assessed over a two year survey period. Lamb weaning percentages were 76% and 71% for 2014/2015 and 2015/2016 respectively. This is in contrast to commercial herds that achieve 131-171%. Livestock owners in Ntshiqo purchased inputs for their livestock, made up primarily of internal parasite control for sheep, but also feed and antibiotics for cattle and sheep. The weaning percentage for cattle in Ntshiqo was 69% for 2014/2015 and 14% in 2015/2016. The low weaning rate is attributed to a low calving rate of 43%, compounded by one farmer losing four calves. No increases in disease occurrence was observed, however the onset of the rain in 2015/2016 occurred only January 2016, meaning that limited fodder would be available in the first half of summer for that season.

In Muden, weaning rates for calves was 37% in 2014/2015 and 0% for 2015/2016 due to the drought. Between June 2015 and February 2016, the cattle owned by the 12 farmers being surveyed declined from 160 to 12 animals due to deaths as a result of the drought. For goats, weaning percentages were 37% and 53% for 2014/2015 and 2015/2016 respectively. Unlike the livestock owners in Ntshiqo, farmers in Muden spend little money on inputs, indicating that they were more resource poor than their Ntshiqo counterparts.

Winter grazing in cropping fields and homestead gardens were considered critically important for feeding livestock in the winter months. While farmers can control access to their own homestead gardens, communal cropping fields, which have individual user rights in summer, become common property in winter.

7.2.2 Water productivity of RWH&C demonstrations in homestead gardens

In terms of yield at the Ntshiqo research sites, mixed results were achieved. In 2013/2014, the RWH&C treatment performed better at two of the four sites, while in 2014/2015 RWH&C performed better at three of the five sites that were planted. In 2015/2016, the delay in the onset of rain resulted in poor germination of the maize crop.

From a soil water content perspective, higher soil water content at all of depths was observed for the RWH&C sites, when compared with the control sites, suggesting that RWH&C did improve soil water content. The seemingly contradictory outcome of variable performance between the treatment and control, while there was consistently higher soil water in the RWH&C treatment was firstly attributed to, high rainfall that occurred about a week after germination in the 2013/2014 growing season. This resulted in ponding of water at the base of the RWH&C contours and resulted in low germination, particularly at the Mjali and Madosini sites. Secondly, ineffective weed control during the early stages of plant growth was also a contributing factor in the 2014/2015 season.

The drought in Muden meant that no results were obtained at the Fabeni site. In Mxheleni, yields were recorded in two of the three years, with crop failure being experienced in 2014/2014 as a result of the drought. Yields from the RWH&C treatments were higher compared with the control when yields were obtained. Cob size and grain yield per cob were also higher in the RWH&C treatment when compared with the control. An additional benefit at Mxheleni of the stone contour bunds are that they are a permanent fixture and will not be damage by livestock or rainfall events causing erosion. Furthermore, the stone bunds trapped substantial amounts of sediment, increasing soil depth and consequently the volume of water that could be stored in the soil. While requiring a substantial labour input during establishment, these are structures that will benefit the Mxheleni farmers in the long term.

The AquaCrop model performed well with respect to modelling yield and water productivity responses to RWH&C compared with the control. However the model overestimated yields in both the RWH&C treatment and the control. This is attributed to low use of fertiliser inputs and poor control of weeds and other management factors by farmers at the research sites.

Observed crop water productivity at Ntshiqo ranged from 0.62 to 1.24 $kg.m^{-3}$ (R2.28 to R4.60 per m^3) water in the RWH&C treatment and 0.29 to 1.28 $kg.m^{-3}$ (R1.09 to R4.74 per m^3) water in the control. The literature provides values ranging from 0.98 to 2.30 $kg.m^{-3}$, suggesting that water productivity for the research sites were at the lower end of the spectrum.

7.2.3 Livestock water productivity

From a livestock water productivity perspective, an understanding of the Descheemaeker model was established and interventions for improving LWP were considered. This concept is still fairly new. An analysis of the research outputs in terms of the feed management component of the framework found biomass production to be significantly higher in the exclosures compared to grazed areas. No difference in ADF, NDF, CP and P values was found between the exclosures and grazed areas during the same time frames. The full summer rest produced significantly higher biomass than the short summer rest. Continuous full summer rotational rests are proposed for Ntshiqo to increase forage quantity and build vigour. Grazing management promotes ecosystem functioning through the prevention of land degradation and soil erosion, which ultimately can result in improved rangeland productivity, water conservation and improved hydrological processes, thereby improving livestock production and contributing to the overall improvement of livestock water productivity.

Protein supplementation was found to have a positive effect on the body condition score of livestock (specifically sheep at Ntshiqo). There was a significant difference between sheep in the treatment and sheep in the control group in all the months (June-September). Data obtained in the FGDs revealed that protein supplementation decreased the number of deaths of sheep during winter, improved the body mass of sheep and the milk yields of ewes. This was supported by published literature. Winter supplementation with protein licks, combined with proper grazing management, has the potential to dramatically improve livestock water productivity through improved livestock performance.

The estimation of livestock water productivity suggested a value of livestock products of R2.2 million, with an estimated evapotranspiration of 18 million m^3 from the rangelands, croplands and homestead gardens, giving a livestock water productivity of R0.12 m^{-3}. This is substantially lower than evidence from the literature, which suggests values of R4.20 – R8.40 per m^3.

7.2.4 Requirements for outscaling of RWH&C in crop and rangelands

From a cropping perspective, RWH&C stands a good chance of performing well in dry areas, however, extreme drought conditions in Muden meant that in poor results were obtained. Rainwater harvesting provided the opportunity for farmers to understand alternative ways of storing water, and outcomes from workshops and FGDs indicate that farmers understood the concept. Farmers from Ntshiqo may have not seen the value of RWH&C because its performance was not consistent with respect to yields. The study revealed that RWH&C has potential however, to be successful if proper agronomic management practices are in place. Weeding in particular proved to be a great problem. The lack of effective weeding at a number of the sites resulting in increased competition for water and nutrients, which negatively affected research results.

At Fabeni in Muden, failure due to the prevailing drought means that farmers are unlikely to adopt RWH&C, Given the high temperatures and variable rainfall, famers aim to keep their production inputs as low as possible due to the risk of crop failure. While farmers acknowledged that crops initially performed better under the RWH&C treatment, ultimately all crops failed, poignantly captured by one farmer who said ‘when we live in such a dry place, there is no guarantee of a return on our investment in terms of increased yield – our crops failed and rainwater harvesting didn’t help’.

At Mxheleni in Muden, the Mxheleni women’s group acknowledged that there were certainly benefits to RWH&C, and some had started building stone contours to harvest water. The high labour requirements were however considered to be a constraint to many members of the group.

Proposed strategies to improve rangeland condition and in turn livestock water productivity include the introduction of fire as a management tool to remove moribund material to counter the effects of selective grazing and to promote the spread of *Themeda triandra*, an important grazing species. A biennial spring burn is suggested, however this would require a change in rules, as currently the burning of grassland is forbidden. This is because standing winter biomass is an important feed source for communal livestock, as well as the risk of wildfires. Annual resting of one quarter of the veld area (i.e. a four year rotational rest) will substantially increase biomass production in the short term and, if implemented in conjunction with a burn, would improve feed quality and species composition and vigour in the long term. Proper control of livestock would be required for this. Rangers were employed during the resting experiments and these were effective at excluding livestock from the rested areas. This would require funding through government grants or from the livestock owners. While there was agreement regarding the benefits of the rest, this system did not continue after the experiments. This is attributed to unwillingness of livestock owners to bear the financial burden of employing rangers and a general lack of organisation among livestock owners. One option to consider for achieving better grazing management is to engage farmer-leaders, such as Mr Tshabu, to lead and coordinate the implementation of a rotational resting system. Given the concerns of fires in communal areas, a proper fire management system with firebreaks would be required to ensure fires do not spread to non-target areas. One option for fire management is to encourage the provincial department of agriculture, in partnership with the community, to partner with the Working on Fire programme to assist with controlled burns.

Feed supplementation through protein licks and the planting of vetch and oats as winter fodder in homesteads showed great promise in improving livestock condition and performance. When feedback was provided to farmers on these options, there was great interest in taking this forward and contact details to source the fodder and the protein lick were provided. Most farmers are resource limited smallholder subsistence farmers and the cost of purchasing these inputs is likely to be limiting for them.

In order for these production benefits to be achieved, however, the full value of livestock products needs to be realised. In addition to food products, raw materials such as wool and manure play an important role in local livelihoods. An important element in realising value from livestock is to increase offtake or sales to firstly generate income and secondly to reduce pressure on the grazing resource. This would require the introduction of new markets for livestock.

Ntshiqo residents provided positive feedback regarding the tested technical interventions. Ensuring 'buy-in' and support from local smallholder farmers are key for the adoption and success of specific interventions. However, a degree of behavioural change is required by local community members through efficient institutional structures which need to be driven by traditional authorities and government to create a policy environment that promotes the adoption of the technical interventions in the long term. Ultimately, a collaborative management approach through integrating technical, institutional and policy interventions remains the key to improve livestock water productivity, safeguard the environment and improve the livelihood benefits for smallholder farmers in Ntshiqo. This requires sustained and long term engagement with traditional authorities, provincial departments of agriculture and the community concerned to implement effective institutional policies to govern crop, livestock and natural resource management. A critical element to be addressed is the absence of effective government agricultural extension services. This can to some extent be ameliorated by supporting NGO-led interventions to support improved institutional frameworks for management of communal areas with sufficient long term funding, however government extension as an organisation needs be more accountable to their constituency in providing the services that they need. It is acknowledged that the lack of human, technical and financial resources in extension services is a challenge, but proper accountability and performance management within the leadership is also necessary to ensure that timeous and appropriate support is provided.

The livestock water productivity concept and framework have proved to be useful in identifying viable technical interventions to improve livelihoods, environmental health, livestock production and overall LWP. This is important in increasing the resilience of smallholder farmers in mixed crop-livestock systems against vulnerabilities such as water scarcity, livelihood failures and climate change.

From an upscaling and outscaling perspective, farmers reported positively regarding the benefits of RWH&C in crop production. However, the additional labour (for weeding in particular) and costs of land preparation are likely to be a major constraint to upscaling and outscaling. Upscaling and outscaling are not likely to be achieved without government funded RHW&C support and development programmes and the training of extension officers on RWH&C practices. The contour bund system applied at the research sites, which resulted in large gaps between the crop rows meant that farmers had to weed constantly. In contrast, under current practices, farmers broadcast seed at high plant populations such that only one weeding is required when the crop is at knee height. Because of the dense plantings, the canopy forms soon after the initial weeding and no further weeding is required. One option is to apply the contour system to minimise runoff and increase infiltration, but to plant along the contours and within the runoff generating areas. This will not concentrate water at the base of the crop (as was the case when the crop was established along the contours), but would reduce water losses from the cropping area in general.

Engaging with farmer-leaders to drive adoption of new techniques is a very good way of achieving upscaling and outscaling of RWH&C. In Ntshiqo, Mr Tshabu is a good example of this. Identifying and supporting farmers who are facilitators of change and development should be supported. This can be achieved through partnerships with government and local NGOs.

Mr Tshabu has also been instrumental in getting farmers involved in the various livestock and crop production programmes that are funded by the Department over the last ten years. The active role of Mr Tshabu highlights how individual action and leadership can leverage benefits for the broader community. Although Mr Tshabu does benefit personally from this in that he has a large flock of sheep and herd of cattle, is a planting contractor for the programme, and has also received grain storage silos, his active pursuit of programmes has made a difference for many other people at Ntshiqo. Had Mr Tshabu not stood to benefit personally from this, it is unlikely that local organisations wold have been established, to the detriment of a number of farmers at Ntshiqo.

Proper extension support and training of extension workers and farmers is critical to achieve upscaling and outscaling. Extension services should be working with farmers in planning, production, harvesting and marketing, however this is currently not being done. The private sector, as evidenced by the participation of BKB, NWGA, NERPO and more recently, GrainSA in Ntshiqo, also have an important role to play in ensuring exposure to new techniques. NGOs also play an important role in providing support to farmers for the adoption of a new technology.

Critically, the inclusion of RWH&C in government policies and programmes is necessary for outscaling. RWH&C should be highlighted as a climate smart agricultural practice for adoption by farmers.

7.3 Lessons learnt

In terms of the cropping research, a key factor affecting the research results was the lack of weeding in the homestead gardens. This was a result of the spacing of the arrangements of the selected RWH&C practice. A possible option is to maintain the contours as they are, but plant the field completely and densely. This will provide good cover and eliminate the need for multiple weeding events, while still maintaining soil and water conservation in the homestead gardens.

The declining use of arable fields, as noted by other researchers, was also noted at Ntshiqo and Muden. When farmers no longer received Government subsidies for production in fields in 2014/2016, production in the fields declined dramatically. This suggests that farmers consider crop production in fields to be too risky. Some of the risks include theft, damage by livestock and drought. In Muden, some farmers no longer use their fields for cropping due the risk of drought. While farmers consider their land tenure to be secure, the lack of a formal or semi-formal rental market may be a factor inhibiting investment in arable fields.

There is a need to give attention to recording livestock numbers and productivity to assess the impact of livestock numbers on communal land and the impact of interventions to improve livestock water productivity.

While a participatory method was used to select and explore RWH&C techniques, it must be acknowledged that there is no 'one size fits all'. In Ntshiqo, conservation agriculture techniques might have better served farmers, while in Muden, given the level of drought, which could not be anticipated at the start of the project, introduction of more drought tolerant maize varieties and other drought tolerant crops may have been more important than the introduction of RWH&C techniques.

7.4 Way forward and future research requirements

Suggestions for future research include testing RWH&C systems in conjunction with formalised land rental schemes to determine whether this tenure exchange option is attractive to farmers. It may well be that farmer-leaders with a more commercial focus, like Mr Tshabu, would benefit from such arrangements. However, the risk of 'capture of the commons' would need to be mitigated through strong institutional frameworks.

Policy interventions are also necessary to secure the wider adoption of RWH&C practices. This should consider some form of subsidisation for farmers, who highlighted in particular the cost of land preparation as a major constraint. Furthermore, the inclusion of RHW&C as a climate smart agricultural practice should be supported.

The experiments for resting of veld showed a dramatic improvement in rangeland biomass production, however the quality of the forage did not improve significantly and no change in species composition in favour of more palatable species was observed. Longer term experiments (greater that five years) are required to determine the impact of improved management of rangelands on livestock water productivity in a communal context.

For the livestock and crop water productivity concepts to be widely and successfully applied, numerous research gaps need to be filled. Theoretical strategies have been proposed for improving livestock water productivity, however, there is a need for real-world assessment on the effectiveness of such interventions. Research needs to identify incentive mechanisms for communities in order to enhance the adoption and investment in land and water management strategies that improve water productivity. Additional research is required on resting in communal rangelands and the relationship between this and livestock water productivity. Furthermore, future research is required to test the potential effects of the integration of various technical, institutional and policy interventions on livestock water productivity in developing countries.

The value of livestock products and outputs require further investigation. In particular, factors that will increase income, including improving yields and quality of wool, encouraging offtake of excess livestock and the nutrient value of manure as a farm input and the extent to which it can substitute mineral fertilisers, in terms of cost and nutrient availability.

8 REFERENCES

Abegaza, A., van Keulena, H. Oosting, S. 2007. Feed resources, livestock production and soil carbon dynamics inTeghane, Northern Highlands of Ethiopia. *Agricultural Systems* 94 (2007) 391–404

Acocks, J.,1988. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa.

African Development Bank (AFDB). 2008. *Rainwater Harvesting Handbook. Assessment of best practices and experience in water harvesting*. Online [http://www.rural-water-supply.net/en/resources/details/268] Accessed 12/08/12

Akbar, M. A., Ahmed, T. U. and Mondal, M. M. H., 2006: Improving Animal Productivity and Reproductive Efficiency: Development and Testing Medicated Ureamolasses Multi-Nutrient Blocks in Rural Farms of Bangladesh. In: *Improving Animal Productivity by Supplementary Feeding of Multi-Nutrient Blocks, controlling Internal Parasites, and enhancing utilization of alternate feed resources*. Vienna: International Atomic Energy Agency (IAEA), Pg 13-28.

Alcock, R. and Hornby, D. 2004. Traditional land matters: a look into land administration in tribal areas in KwaZulu-Natal. Pietermaritzburg: Legal Entity Assessment Project.

Aliber, M. and Hall, R. 2010. *Development of evidence-based policy around small-scale farming. Programme for Support to Pro-Poor Policy Development*. Online [www.psppd.org.za] Accessed 8 November 2012.

Alliber, M. and Hart, T., 2009. Should subsistence farming be supported as a strategy to address rural food security. *Agrekon*, 48, 434-458.

Altman, M. Hart, T. Jacobs, P. 2009. *Food security in South Africa*. Pretoria: Human Sciences Research Council: Centre for Poverty, Economics and Growth.

Amede, T., Geheb, K. and Douthwaitec, B., 2009: Enabling the uptake of livestock-water productivity interventions in the crop-livestock systems of SSA. *The Rangeland Journal*, 31, 223-230.

Arellano, D., Friedberg, E. and March, J., 2011: Institutions and Organizations: Differences and Linkages from Organization Theory. *Gestion Politica Publica*, 20, 235-246.

Assefa, G. and Ledin, I., 2001: Effect of variety, soil type and fertiliser on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. *Animal Feed Science and Technology*, 92, 95-111.

Australia Bureau of Statistics (ABS).2012 Agricultural Resource Management Practices, Australia, 2011-12. Online [http://www.abs.gov.au/ausstats/abs@.nsf/lookup/4630.0main+features72011-12] Accessed 12 January 2017.

Backeberg, G. 2009. Improving rural livelihoods with rainwater harvesting and conservation in communal croplands in South Africa: Opportunities and obstacles. *Paper presentation: Second International Seminar of the International Foundation for Sustainable Development In Africa and Asia,* Gottingen, Germany, 14-16 July 2009.

Badisa, K. 2011. Socio-economic factors determining in-field rainwater harvesting technology adoption for cropland productivity in Lambani village: A case study of Thulamela Local Municipality of the Vhembe District in Limpopo province. Dissertation, Faculty of Science and Agriculture, University of Limpopo

Ball, D. M., Collins, M., Lacefield, G. D., Martin, N. P., Mertens, D. A., Olson, K. E., Putnam, D. H., Undersander, D. J. and Wolf, M. W., 2001: Understanding forage quality. Park Ridge, Illinois: American Farm Bureau Federation Publication 1-01.

Barnes, D. L. and Dempsey, C. P., 1992: Influence of period of deferment before stocking spring-burnt sourveld on sheep performance and veld productivity. Journal of the Grassland Society of Southern Africa, 9, 149-157.

Barnes, D. L., 1989c: Reaction of three veld grasses to different schedules of grazing and resting. 1. Patterns of shoot growth. *South African Journal of Plant and Soil*, 6, 1-7.

Barnes, D. L., 1992: A critical analysis of veld management recommendations for sourveld in the south-eastern Transvaal. *Journal of the Grassland Society of Southern Africa*, 9, 126-134.

Bayer et al (undated) – think this the reference below – change in report

Beauchemin, K. A., 1996: Using ADF and NDF in dairy cattle diet formulation- a western Canadian perspective. *Animal feed Science Technology*, 58, 101-111.

Benayas, J. Martins, A. Nicoulau, J and Schulz, J. 2007. Abandonment of agricultural land: an overview of drivers and consequences. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 2007 **2** No. 57

Boers, M. and Ben-Asher, J. 1982. A review of rainwater harvesting. *Agricultural water management 5:145-15*

Botha, J. van Staden, P. Koatla, B. Anderson, J. and Joseph, F. 2014. *Rainwater harvesting and conservation (RWH&C) for cropland and rangeland productivity in communal semi-arid areas of South Africa.* Report to the Water Research Commission. Report no. 1775/1/14.

Botha, JJ. Anderson, JJ. Groenewald, DC. Nhlabatsi, NN. Zere, TB. Mdibe, N and Baiphethi, MN. 2007. *On-farm application of in-field rainwater harvesting techniques on small plots in the central region of South Africa Volume 1 of 2*. Report to the Water Research Commission. WRC Report no TT313/07.

Bouman, B. 2007. A conceptual framework for the improvement of crop water productivity at different scales. *Agricultural Systems (93) 43-60*

Briske, D. D., Derner, J. D., Brown, J. R., Fuhlendorf, S. D., Teague, W. R., Havstad, K. M.,Gillen, R. L., Ash, A. J. and Willms, W. D., 2008: Rotational Grazing on Rangelands: Reconciliation of Perception and Experimental Evidence. *Rangeland Ecology and Management*, 61, 3-17.

Butler, M. 2002. *Traditional Authorities: Know where to land (Traditional authority and land in KwaZulu-Natal)*. Association for Rural Advancement. Pietermaritzburg

Camp, K. G. T., 1995: *The Conservation Status of the Weenen Valley Bushveld*. KwaZulu-Natal Department of Agriculture. Cedara, Cedara Report No. N/A/95/16.

Camp, K. G. T., 1997d: Resting of Veld. In: K. G. T. Camp and J. M. B. Smith, eds. *Veld Management Planning in KwaZulu-Natal*. KwaZulu-Natal Department of Agriculture. Cedara, Cedara Report No. N/A/97/5.

Christen, R and Anderson, J. 2013. Segmentation of Smallholder Households: Meeting the Range of Financial Needs in Agricultural Families. Focus Note 85. Washington, D.C.: CGAP, April.

Claasens, A. 2001. *'It is not easy to challenge a chief': Lessons from Rakgwadi*. PLAAS, School of Government, University of the Western Cape. Research Report No. 9, October 2001.

Cleasby, T. G., 1963: The Feeding Value of Molasses. Proceedings of The South African Sugar Technologists Association, 113-117.

Cleaver, F., 2000: Moral ecological rationality, institutions and the management of common property resources. *Development and Change*, 31, 361-383.

Cousins, B. 2011. *Imitetho yomhlaba yaseMsinga: The living law of the land in Msinga, KwaZulu-Natal.* Institute for Poverty, Land and Agrarian Studies. Research Report No. 43

Crettenden. J. and Holbery, S. Undated. Management strategies to improve lamb weaning percentages South Australian Research and Development Institute (SARDI), Minnipa Agricultural Centre. Online [www.msfp.org.au/wp-content/uploads/Management-strategies-to-improve-lamb-weaning-percentages.pdf] Accessed 12 January 2017

Critchley, W. and Siegert, K. 1991. *A Manual for the design and construction of water harvesting schemes for plant production*. Food and Agricultural Organisation of the United Nations. Rome.

Crookes, T. and Lyne, M. 2001. Improvements in the rental market for cropland in a communal region of KwaZulu-Natal. Agrekon, 40(4): 669-677.

Danckwerts, J. 1989. Sweet Grassveld. I*n: Danckwerts, J and Teague, W. (eds). Veld management in the Eastern Cape.* Department of Agriculture and Water Supply, Government Printer, Pretoria

De Beer, L., 2012: The Wool Development Program in Communal Areas of South Africa. In: *Strategies to Overcome Poverty and Inequality- Towards Carnegie III*. 3 – 7 September 2012. University of Cape Town.

De Brouwer, C. H. M., Cilliers, J. W., Vermaak, L. M., van der Merwe, H. J. and Groenewald, P. C. N., 2000: Phosphorus supplementation to natural pasture grazing for beef cows in the Western Highveld region of South Africa. *South African Journal of Animal Science*, 30, 43-52.

De Bruyn, T. and Koster, H., 2000: Application of licks on veld. In: A. Engelbrecht, K. Kirkman and A. Swanepoel, eds, 2004, later date. *Veld and pasture management guidelines for sustainable animal production on the Mpumalanga Highveld*. Mpumalanga, South Africa: Department of Agriculture. pp 23-24.

De Bruyn, T. Undated. The condition, productivity and sustainability of communally grazed rangelands in the central Eastern Cape Province. [online: www.ais.up.ac.za/vet/goat/documents/sec18.pdf] Accessed 15 December 2012

De Wit, C. 1992 Resource use efficiency in agriculture. *Agricultural Systems* **40** (1992) 125-151.

Delgado, C., 1999: Sources of growth in smallholder agriculture in SSA: the role of vertical integration of smallholders with processors and marketers of high-value items. *Agrekon*, 38, 165-189.

Dengu, T. and Lyne, M. 2007. Secure land rental contracts and agricultural investment in two communal areas of KwaZulu-Natal. *Agrekon, Vol 46, No 43 (September 2007).*

Denison, J and Wotshela, L. 2009. *Indigenous water harvesting and conservation practices: Historical context, cases and implications*. Report to the Water Research Commission. WRC Report No TT392/09.

Denison, J. Murata, C. Conde, L. Perry, A. Monde, N. Jacobs, T. 2015. Empowerment of women through water use security, land use security and knowledge generation for improved household food security and sustainable livelihoods in selected areas of the Eastern Cape. WRC Report No 2083/1/15

Denison, J. Smulders, H. Kruger, E. Ndingi, H. and Botha, M. 2011. Water harvesting and conservation. Volume 2 Part 1: Technical Manual and Farmer Handouts. Report to the Water Research Commission. WRC Report No. TT493/11.

Descheemaeker, K. Amede, T and Haileslassie, A. 2010. Improving water productivity in mixed crop-livestock farming systems of sub-Saharan Africa. *Agricultural Water Management 97 (2010) 579-586*.

Descheemaeker, K., Amede, T. and Haileslassie, A., 2009: Livestock and Water Interactions in Mixed Crop-Livestock Farming Systems of SSA: Interventions for Improved Productivity. Working Paper 133. Colombo: International Water Management Institute.

Descheemaeker, K., Amede, T. and Haileslassie, A., 2010a: Improving water productivity in mixed crop-livestock farming systems of SSA. *Agricultural Water Management*, 97, 579-586.

Descheemaeker, K., Bossio, D., Amede, T., Ayalneh, W., Haileslassie, A. and Mapedza E., 2011: Analysis of gaps and possible interventions for improving water productivity in crop livestock systems of Ethiopia. *Experimental Agriculture*, 47, 21-38.

Descheemaeker, K., Bunting, S.W., Bindraban, P., Muthuri, C., Molden, D., Beveridge, M., van Brakel, M., Herrero, M., Clement F., Boelee, E., Jarvis. D.I., 2013 Increasing Water Productivity in Agriculture. CAB International. Managing Water and Agroecosystems for Food Security

Descheemaeker, K., Nyssen, J., Poesen, J., Raes, D., Haile, M., Muys, B. and Deckers, S., 2006: Runoff on slopes with restoring vegetation: A case study from the Tigray highlands, Ethiopia. *Journal of Hydrology*, 331, 219-241.

Descheemaeker. K., Amede, T., Haileslassie, A. and Bossio, D., 2011. Analysis of gaps and possible interventions for improving water productivity in crop livestock systems of Ethopia. *Explor Agric*, 47, 21-38.

Dovie, D, B. K., Shackleton, C. M. and Witkowski, E. T. F., 2006: Valuation of communal area livestock benefits, rural livelihoods and related policy issues. *Land Use Policy*, 23, 260- 271.

Dube, E., 2012: Soil fertility enhancement through appropriate fertilizer management on winter cover crops in a conservation agriculture system. Unpublished MSc thesis. University of Fort Hare.

Eskandari, H., Ghanbari, A. Javanmard, A., 2009: Intercropping of Cereals and Legumes for Forage Production. *Notulae Scientia Biologicae*, 1, 7-13.

Everson, C. Everson, TM. Modi AT. Csiwila, D. Fanadzo, M. Naiken, V. Auerbach, R. Moodley, M. Mtshali, SM. Dladla, RM. 2011. *Sustainable techniques and practices for water harvesting and conservation and their effective application in resource-poor agricultural production through participatory adaptive research.* Report to the Water Research Commission. WRC Report no. 1465/1/11.

Everson, C. S. and Tainton, N. M., 1984: The effect of thirty years of burning on the Highland Sourveld of Natal. *Journal of the Grassland Society of Southern Africa*, 1, 15-20.

Everson, T. M. and Smith, J. M. B., Undated: Improving Rural Livelihoods through Biogas Generation using Livestock Manure and Rainwater Harvesting. Water Research Commission. WRC Report No K5/1955/15 (In Press).

Everson, T. M., Yeaton, R. I. and Everson, C. S., 2009: Seed dynamics of *Themeda triandra* in the montane grasslands of South Africa. *African Journal of Range & Forage Science*, 26, 19-26.

Fair, J., 2013: Producing better Highveld beef. *Farmer's Weekly*.

Fidelibus, M. W. and MacAller, R. T. F., 1993: Methods for plant sampling, Restoration in the Colorado Desert: Management Notes. Prepared for California Department of Transportation, San Diego, p. 1-7.

Food and Agricultural Organization (FAO). 2009. *The State of Agricultural Commodity Markets.* Rome, Italy: Food and Agricultural Organization of the United Nations

Food and Agriculture Organisation (FAO). 2001. Mixed crop-livestock farming: A review of traditional technologies based on literature and field experiences, *FAO Animal Production and Health Papers 152*. Online [www.fao.org/docrep/004/Y0501E/Y0501E00.HTM] Accessed 10 January 2013.

Gqokoma, D. 2005. *Is land tenure a significant variable for promoting agricultural productivity in rural villages? The case study of Nonkcampa village in the Buffalos City Municipality*, Eastern Cape, South Africa. Masters in Rural Development Thesis, University of Fort Hare.

Haileslassie, A. Peden, D. Gebreselassie, S. Amede, T. and Descheemaeker, D. 2009. Livestock water productivity in mixed crop-livestock farming systems of the Blue Nile basin: assessing variability and prospects for improvement. *Agricultural Systems*, Vol. 102 Nos 1/3, pp. 33-40

Hatch, G. P., 1991: Species and area selection patterns in the Southern Tall Grassveld of Natal. Unpublished MSc Thesis. University of Natal: Pietermaritzburg.

Hatibu, N. and Mahu, H. 1999. Rainwater harvesting technologies for agricultural production: A case for Dodoma, Tanzania in: Kaumbutho P G and Simalenga T E (eds*) Conservation tillage with animal traction. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA*). Harare. Zimbabwe. 173p.

Havemann, T. and Muccione, V., 2011: Mechanisms for agricultural climate change mitigation incentives for smallholders. Copenhagen, Denmark: CCAFS. (CCAFS Report Nr 6). http://hdl.handle.net/10568/12496 (Accessed 1 October 2015).

Hebinck, P & Van Averbeke, W. 2013. What constitutes 'the agrarian' in rural Eastern Cape African settlements? In: Hebinck, P. & Cousins, B. *In the shadow of policy: Every day practices in South African land and agrarian reform*. Johannesburg: Wits University Press: 189-203.

Helmreich, B. and Horn, H., 2009: Opportunities in rainwater harvesting. *Desalination*, 248, 118- 124.

Hodgson, G. M., 2006: What Are Institutions? *Journal of Economic Issues*, 40, 1-25.

International Water Management Institute (IWMI). 2003. *Definition of RWH.* Online [www.iwmi.org] Accessed 25 November 2012]

International Water Management Institute (IWMI). 2011. *Poster presentation: COP17 Climate Change Conference.* Online [http://www.iwmi.cgiar.org/News_Room/Archives /Durban_Climate_Change_Conference/PDF/infield.pdf] accessed 20/08/12.

Jaleta M, Gebremedhin B. 2010. Crop-Livestock Interactions in Smallholders' Market Participation: Evidence from Crop-Livestock Mixed Systems in Ethiopia. *Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa*, September 19-23, 2010.

Kazianga, H. and Udry, C., 2006: Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso. *Journal of Development Economics*, 79, 413-446.

Keftasa, D., 1988: Role of crop residues as livestock feed in the Ethiopian highlands. In: B. H. Dzowela, ed. *African Forage Plant Genetic Resources, Evaluation of Forage Germoplasm and Extensive Livestock Production Systems*. Addis Ababa, Ethiopia: ILCA.

Kessler, M. Undated. Goat Farming by the Numbers. Online [http://www.boergoats.com /clean/articleads.php?art=887] Accessed 12 August 2016.

Kijne, J.W., Barker, R., and Molden, D. (eds) (2003) Water Productivity in Agriculture: Limits and Opportunities for Improvement. *Comprehensive Assessment of Water Management in Agriculture Series 1. CAB International, Wallingford, UK in association with International Water Management Institute (IWMI), Colombo.*

Kirkman, K. P. and De Faccio Carvalho, P. C., 2003: Management interventions to overcome seasonal quantity and quality deficits of natural rangelands. In: N. Allsopp, A. R. Palmer, S. J. Milton, K. P. Kirkman, G. I. H. Kerley, C. R. Hurt and C. J. Brown, eds. *Rangeland in the New Millenium*. Proceedings of the VII International Rangeland Congress, Durban. pp. 1289-1297.

Kirkman, K. P. and Moore, A. 1995: Perspective: Towards improved grazing management recommendations for sourveld. *African Journal of Range & Forage Science*, 12, 135-144.

Kirkman, K. P., 2002a: The influence of various types and frequencies of rest on the production and condition of sourveld grazed by sheep or cattle. 1. Proportional species composition. *African Journal of Range and Forage Science*, 19, 55-62.

Kirkman, K. P., 2002b: The influence of various types and frequencies of rest on the production and condition of sourveld grazed by sheep or cattle. 2. Vigour. *African Journal of Range and Forage Science*, 19, 93-106.

Lalman, D., Undated: Nutrient Requirements of Beef Cattle. Oklahoma: Oklahoma Cooperative Extension Service. E-974.

Lemaire, G., Franzluebbers, A., De Faccio Carvalho, P. C. and Dedieu, B., 2014: Integrated crop-livestock systems: Strategies to achieve synergy between agricultural production and environmental quality. *Agriculture, Ecosystems and Environments*, 190, 4-8.

Livestock Working Group (LWG)., 2015: Personal communication. Focus Group Discussions: Ntshiqo, Eastern Cape (18 June 2015; 21 July 2015; 13 August 2015; 16 September 2015).

Louw, A., Ndanga, L. and Chikazunga, D., 2008: Restructuring food markets in the SSA region: Dynamics in context of the fresh produce subsector. A synthesis of country findings. Regoverning Markets - Small scale producers in modern agrifoodmarkets. University of Pretoria.

Lütge, B. U., Hardy, M. B. and Hatch, G. P., 1996: Plant and sward response to patch grazing in the Highland Sourveld. *African Journal of Range & Forage Science*, 13, 94-99.

Mabhaudi, T. Chirabada, T and Modi, A. 2016. Water-Food-Nutrition-Health Nexus: Linking Water to Improving Food, Nutrition and Health in Sub-Saharan Africa. *Int. J. Environ. Res. Public Health* **2016**, 13, 107

Machingura, C., 2007: An analysis of factors that can be used to identify successful smallholder farmers: A case study of Mbhashe and Ngqushwa. Unpublished MSc Thesis. University of Fort Hare.

Manona, S and Baiphethi, M. 2008. *Developing a land register and a set of rules for application of in-field rainwater harvesting in three villages in Thaba Nchu: A pilot project*. Report to the Water Research Commission. WRC Report no TT 367/08.

Mapako, L., 2011: Assessment of Vegetation Diversity and Rangeland Condition in the Highveld Communal Grazing Lands of Swaziland. Unpublished MSc Thesis. Windhoek: University of Namibia.

Mapiye, C., Chimonyo, M., Dzama, K., Raats, J. G. and Mapekula, M., 2009: Opportunities for improving Nguni cattle production in the smallholder farming systems of South Africa. *Livestock Science*, 124, 196-204.

Martindale, G., 2007: Influence of livestock grazing on plant diversity of Highland Sourveld grassland in KwaZulu-Natal. Unpublished MSc Thesis. University of Witswatersrand, Johannesburg.

Marx, D. L., 2011: An assessment of ecological impacts of community-based restoration on communal grasslands in the Drakensberg foothills. Unpublished MSc Thesis. University of Cape Town.

Maura, A., Ainslie, A. and Shackleton, C., 2003: Land use and livelihoods. In: S. Heyns, ed. *Programme for Land and Agrarian Studies*. Cape Town: Programme for Land Agrarian Studies. (Evaluating Land and Agrarian Reform in South Africa, occasional paper series, No. 8).

McCosh, J. Nxele, Z. Letty, B. Dlamini, B. and Parry, A. 2012. A review of collective and individual action by banana growers and other farmers in Bizana Municipality. *WRC project*

K5/1879//4: Analysis of food value chains in rain-fed and irrigated agriculture to include emerging farmers in the mainstream of the economy.

Meissner, H. H., 1982: Substitutions values of various classes of farm and game animals in terms of a biologically defined large stock unit. Farming in South Africa. Beef Cattle C3/1982.

Meissner, H. H., Zacharias, P. J. K. and O'Reagain, P. J., 1999: Forage Quality (feed value). In: N. M. Tainton, ed. Veld Management in South Africa. Pietermaritzburg: University of Natal Press.

Meissner, H. Scholtz, M. and Schönfeldt, H. Undated. *The status, socio-economic and environmental impact, and challenges of livestock agriculture in South Africa*. Online [www.RMRDSA.co.za] Accessed 30/10/2012.

Millar, B. 2010. *Socio-economic drivers of the abandonment of a agricultural fields in the smallholder farming sector in Peddie, Eastern Cape, South Africa*. Online [data.saeon.ac.za/documents/presence-network/thicket...pdf/.../file] Accessed 12 January 2013.

Miller, R. W. and Gardiner, D. T., 1998: *Soils in our environment (8th edition)*. New Jersey, USA: Prentice-Hall Inc.

Moeletsi, M. Shabalala, Z. De Nusschen, G and Walker, S. 2016 Evaluation of an inverse distance weighting method for patching daily and dekadal rainfall over the Free State Province, South Africa. *Water SA* vol.42 n.3 Pretoria Jul. 2016

Molden, D. Oweis, T. Pasquale, S. Kijne, J. Hanjra, A. Bindraban, P. Bouman, B. Erenstein, T. Farahani, O. Hachum, H. Hoogeveen, H. Mahoo, J. Nangia, H. Peden, V. Sikka, D. Silva, A. Turral, P. Upadhyaya, H Zwart, S. 2007. Pathways for increasing agricultural water productivity. *In Molden, D. (Ed.). Water for food, water for life: A Comprehensive Assessment of Water Management in Agriculture*. London, UK: Earthscan; Colombo, Sri Lanka: IWMI. pp.279-310

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M. A. and Kijne, J., 2010: Improving agricultural water productivity: Between optimism and caution. *Agricultural Water Management*, 97, 528-535.

Monde, N. Botha, J. Joseph, F. Anderson, J. Dube, S. and Lesoli, M. 2012. *Sustainable techniques and practices for water harvesting and conservation and their effective application in resource-poor agricultural production.* Report to the Water Research Commission. Report no. 1478/1/12.

Moore, A. and Müller, O., 1994: Poster abstract: Lupin supplementation for pregnant ewes on winter veld at Nooitgedacht A. D. C. *Bulletin of the Grassland Society of southern Africa*, 5, 54.

Morris, C. and Tainton, N., 2002: Lessons from Africa Long-term rangeland trials in an African grassland offer insight on the role fire, fertilizer and rotational grazing play in management of tall grasslands. Rangelands, 24, 8-12.

Morris, C. D., Tainton, N. M. and Hardy, M. B., 1992: Plant species dynamics in the Southern Tall Grassveld under grazing, resting and fire. *Journal of the Grassland Society of Southern Africa*, 9, 90-95.

Mukasa-Mugerwa, E. 1989. A review of reproductive performance of female Bos Indicus (Zebu) cattle. International Livestock Centre for Africa, August, 1989.

Munyai, F. R., 2012: An Evaluation of Socio-Economic and Biophysical Aspects of Small-Scale Livestock Systems Based on a Case Study from Limpopo Province: Muduluni Village. Unpublished PhD Thesis. University of Free State.

Mvinjelwa, S. A., Mapekula, M., Maphosa, V. and Muchenje, V., 2014: Body and fleece weights of woollen sheep in veld communal rangelands of the Eastern Cape Province. *Tropical Animal Health and Production*, 46, 913-918.

National Research Council (NRC)., 1984: *Nutrient requirements of beef cattle*. 6th ed. Washington D. C: National Academy Press.

Ndoro, J. T., Mudhara, M. and Chimonyo, M., 2014: Cattle Commercialization in Rural South Africa: Livelihood Drivers and Implications for Livestock Marketing Extension. *Journal of Human Ecology*, 45, 207-221.

Newman, Y. C., Lambert, B. and Muir, J. P., 2006. Defining forage quality. Texas Cooperative extension. The Texas A & M University System.

Nkwinti, G. 2005. Eastern Cape Livestock Improvement Programme. *Provincial Notice PN 17*.

Nondomiso, F. 2009. *Dynamics of development intervention, the case of Peddie, Eastern Cape*. Master of Social Science Dissertation, University of Fort Hare, March, 2009.

Nongcawula, N. 2014. Personal Communication. District Agricultural Officer, Tsolo. 15 May 2014

North, D. 1992. Institutions and economic theory. *American Economist*, Spring, 1992.

North, D. C., 1993: Institutions and Credible Commitment. *Journal of Institutional and Theoretical Economics*, 149, 11-23.

Ntsebeza, L. 1999. Land tenure reform in South Africa: an example from the Eastern Cape Province. International Institute for Environment and Development.

O'Reagain, P. J. and Mentis, M. T., 1988: Seasonal changes in the quality of diet selected by cattle grazing the natal sour sandveld. *Journal of the Grassland Society of Southern Africa*, 5, 48-51.

Okungoya, F. 2014. Socio-economic factors that affect livestock numbers: A case study of smallholder cattle and sheep farmers in the Free State Province of South Africa. MSc Dissertation.

Oliver, S. M., 2007: Small-Scale Feeding and Habitat Preferences of Herbivore Game Species in the Grassland of the Central Free State. Unpublished MSc Thesis. University of Free State: Bloemfontein.

OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs). 2015. Benchmarks for a Good Lamb Crop Performance Targets for Replacement Ewe Lambs. Online [http://www.omafra.gov.on.ca/english/livestock/sheep/facts/benchmrk.htm]. Accessed 9 September 2015.

Organisation of Economic Cooperation and Development (OECD). Undated. *Defining and measuring productivity.* Online [http://www.oecd.org/std/productivitystatistics/40526851.pdf] Accessed 6 January 2013.

Oweis, T. Hachu, A. and Kijne, J. 1999. *Water harvesting and supplementary irrigation for improved water use efficiency in dry areas*. SWIM Paper 7. Colombo, Sri Lanka: International Water Management Institute.

Oweis, T. Prinz, D. and Hachum, A. 2012. Water Harvesting for Agriculture in the DA. ICARDA, CRC Press/ Balkema, Leiden, the Netherlands

Palmer, A. R. and Bennett, J. E., 2013: Degradation of communal rangelands in South Africa: towards an improved understanding to inform policy. *African Journal of Range and Forage Science*, 30, 57-63.

Peddie, G. M. and Tainton, N. M. and Hardy, M. B., 1995: The effect of past grazing intensity on the vigour of *Themeda triandra* and *Tristachya leucothrix*. *African Journal of Range & Forage Science*, 12, 111-115.

Peden, D. Tadesse, G. and Mammo, M. Undated. Improving the water productivity of livestock: An opportunity for poverty reduction International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia

Peden, D., Amede, T. and Haileslassie, A., 2011: Opportunities for water-efficient livestock production. International Livestock Research Institute. *Livestock Exchange Issue Brief*, 5, 1-5.

Peden, D., Faki, H., Alemayehu, M., Mpairwe, D., Herrero, M., Van Breugel, P., Haileslassie, A., Taddesse, G. and Bekele, S., 2008: Opportunities for increasing livestock water productivity in the Nile River Basin. Proceedings, Nile Basin Development Forum, 1-19.

Peden, D., Tadesse, G. and Misra, A., 2007: Water and livestock for human development. In: *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London, UK: Earthscan and Colombo, Sri Lanka: International Water Management Institute. Pp 485-514.

Perry, C. 2007. Efficient irrigation; inefficient communication; flawed recommendations. *Irrig. and Drain*. **56:** 367–378 (2007)

Pienaar, P. L., 2013: Typology of Smallholder Farming in South Africa's Former Homelands: Towards an Appropriate Classification System. Unpublished MSc Thesis. Stellenbosch: Stellenbosch. University.

Powell, M. J., Pearson, A. R. and Hiernaux, P. H., 2004: Review and Interpretation: Crop-Livestock Interactions in the West African Drylands. *Agronomy Journal*, 96, 469-483.

Pratt, D. J., 1984: Ecology and Livestock. In: J. R. Simpson and P. Evangelou, eds. *Livestock Development in Subsaharan Africa: Constraints, Prospects, Policy.* Colorado: Westview Press.

Quixley, S. 2008. Participatory action research: an outline of the concept. Online [www.suziqconsulting.com.au/free_articles_files/CD%20-%20PAR%20Detailed%20Overview%20-%20Aug08.pdf] Accessed 5 January 2012

Raes, D., Steduto, P., Hsiao, T. C. and Fereres, E. (2009). AquaCrop – The FAOcrop model to simulate yield response to water, 1. Main algorithms and software description. Agronomy Journal 101:4438–4447.

Reas et al 1999 (Zinhle)

Robinson, P., Putnam, D. and Mueller, S., 1998: Interpreting Your Forage Test Report. *California Alfalfa and Forage Review*, 1, 1-2.

Rockstrom, J. Hatibu, N. Oweis, T and Wani, S. 2007. Managing water in rainfed agriculture. In: Comprehensive Assessment of Water Management in Agriculture. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan, and Colombo: International Water Management Institute.

Rota A and Sperandini S. 2010. Integrated crop-livestock farming systems. *Livestock Thematic Papers, Tools for project design*. International Fund for Agricultural Development.

Salami, A., Kamara, A. B. and Brixiova, Z., 2010: Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities. Working Paper Series No. 105. Tunis, Tunisia: African Development Bank.

Salomon, M. 2011. *Keeping cattle in a changing rural landscape: Communal rangeland management in Okhombe, KwaZulu-Natal, South Africa.* PhD Thesis, Centre of Environment, Agriculture, and Development, University of KwaZulu-Natal, Pietermaritzburg, 2011.

Schoeman, S. Cloete, S. and Oliver, J. 2010. Returns on investment in sheep and goat breeding in South Africa. Online [www.repository.up.ac.za/bitstream/handle/2263 /14088/ Schoeman_Returns (2010).pdf?sequence=1] Accessed 12 January 2017

Sithole, P. and Mbele, T., 2008: Fifteen Year Review on Traditional Leadership a Research Paper. Pretoria: Human Sciences Research Council Press.

Smith, J. M. B., 1997: Introduction to Veld Management Principles. In: K. G. T. Camp and J. M. B. Smith, eds. Veld Management Planning in KwaZulu-Natal. KwaZulu-Natal Department of Agriculture. Cedara, Cedara Report No. N/A/97/5.

Smith, J., Sones, K., Grace, D., MacMillan, S., Tarawali, S. and Herrero, M., 2013: Beyond milk, meat, and eggs: Role of livestock in food and nutrition security. *Animal Frontiers*, 3, 6-13.

Snyman, H. 1998. Dynamics and sustainable utilization of the rangeland ecosystem in arid and semi-arid climates of southern Africa. J. *Arid Environ*. 39, 645-666.

Snyman, H. 1999. Quantification of the soil-water balance under different veld conditions in a semi-arid climate. *Afr. J. Range For. Sci*. 16, 108-117.

Snyman, H. A., 2006: Estimating grassland production loss due to fire for a semi-arid climate. *South African Journal of Animal Science*, 36, 38-41.

Sprinkle, J., 2001: Protein Supplementation. In: R. Tronstad, G. Ruyle, and J. Sprinkle, eds. *Arizona Ranchers' Management Guide.* Arizona: *The University of Arizona*. Range Cattle Nutrition 49-56.

Steduto, P., Hsiao, T. C., Raes, D., Fereres, E. (2009). AquaCrop - The FAO crop model to simulate yield response to water, 1. Concepts and underlying principles. Agronomy Journal 101:426–437.

Stewart, B. A., Koohafkan, P. and Ramamoorthy, K., 2006: Dryland Agriculture Defined and Its Importance to the World. In: G. A. Peterson, P. W. Unger and W. A. Payne, eds. *Dryland Agriculture*. Madison, Wisconsin: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.

Suiter, J., 1994: Body condition scoring of sheep and goats. Farmnote 69/1994. Department of Agriculture, Western Australia.

Tainton, N. 1981. The ecology of the main grazing lands of South Africa. *in Veld and Pasture Management in South Africa. edited by N.M.Tainton*. Pietermaritzburg: Shuter & Shooter.

Tainton, N. 1999. Veld management in South Africa. *African Journal Of Range & Forage Science* Vol. 16 , Iss. 2-3,1999

Tainton, N. M. and Danckwerts, J. E., 1989: Resting. In: N. M. Tainton, ed. *Veld Management in South Africa.* Pietermaritzburg: University of Natal Press.

Tainton, N. M., 1981: *Veld and Pasture Management in South Africa*. Pietermaritzburg: Shuter & Shooter.

Tainton, N. M., Aucamp, A. J. and Danckwerts, J. E., 1999: Grazing Programmes. In: N. M. Tainton, ed. *Veld Management in South Africa*. Pietermaritzburg: University of Natal Press.

Tarawali, S., Herrero, M., Descheemaeker, K., Grings, E. and Blummel, M., 2011: Pathways for sustainable development of mixed crop livestock systems: Taking a livestock and pro-poor approach. *Livestock Science*, 139, 11-21.

Tau, M. S., 2005: Grazing Management in the Communal Rangelands of the Upper Thukela, KwaZulu-Natal. Unpublished MSc Thesis. University of KwaZulu-Natal.

Teague, W. R., Trollope, W. S. W. and Aucamp, A. J., 1981: Veld Management in the semi-arid bush-grass communities of the eastern cape. *Proceedings of the Annual Congresses of the Grassland Society of Southern Africa*, 16, 23-28.

Thompson, J.M. and Meyer, H., 1994: Body condition scoring of sheep. Corvallis Extension Service, Oregon State University.

Thornton, P. and Herrero, M. 2010. Mixed crop livestock systems in the developing world: present and future. *Advances in Animal Biosciences* 1(2): 481-482.

Thornton, P. K., Van de Steeg, J., Notenbaert, A. M. and Herrero, M., 2009: The impacts of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know. *Agricultural Systems*, 101, 113-127.

Tittonell, B and Giller, K. 2013. When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research* Volume 143, 1 March 2013, Pages 76–90

Trollope, W. S. W., 1989: Grazing Management Principles and Practices: Veld Burning as a Management Practice in Livestock Production. In: J. E. Danckwerts and N. M. Teague, eds. *Veld Management in the Eastern Cape*. Pretoria: Department of Agriculture and Water Supply.

Trollope, W. S. W., Trollope, L. A. and Bosch, O. J. H., 1990: Veld and pasture management terminology in southern Africa. *Journal of the Grassland Society of Southern Africa*, 7, 52-61.

Tulu, M., 2006: Estimation of livestock, Domestic Use and Crop Water Productivities of SG-2000 Water Harvesting Pilot Projects in Ethiopia. International Livestock Research Institute and International Water Management Institute, Addis Ababa, Ethiopia. Masters Thesis. The Netherlands: Wageningen University.

Turpie, J. and Visser, M., 2012: The impact of climate change on South Africa's rural areas. Chapter 4 in: Financial and Fiscal Commission: Submission for the 2013/2014 Division of Revenue, Johannesburg, South Africa.

Undersander, D., Albert, B., Cosgrove, D., Johnson, D. and Peterson, P., 1993: Pastures for Profit: A Guide to Rotational Grazing. Pub. No. A3529. Madison, WI: University of Wisconsin Cooperative Extension.

van Averbeke, W. 2004. *Technology transfer for poverty reduction in agriculture: a review.* Occasional Paper OP/01/04. Centre for Organic & Smallholder Agriculture (COSA), Department of Agricultural Management, Tshwane University of Technology, Pretoria.

Van Averbeke, W. and Khosa, T. B., 2007: The contribution of smallholder agriculture to the nutrition of rural households in a semi-arid environment in South Africa. *Water SA*, 33, 413-418.

van Ittersum, M, Cassman, K, Grassini, P, Wolf, J. Tittonell, P and Hochman, Z. 2013. Yield gap analysis with local to global relevance – A review. *Field Crops Research* **143** (2013) 4-17

Van Niekerk, B. D. H. and Jacobs, G. A., 1985: Protein, energy and phosphorus supplementation of cattle fed low-quality forage. *South African Journal of Animal Science*, 15, 133-136.

Van Oudtshoorn, F., 2012. *Guide to Grasses of southern Africa*. Pretoria, Briza.

Vetter, S., 2009: Drought, change and resilience in South Africa's arid and semi-arid rangelands. *South African Journal of Science*, 105, 29-33.

Vink, N. and Kirsten, J., 2003: Agriculture in the national economy. In L. Niewoudt and J. Groenewald, eds. *The Challenge of Change: Agriculture, Land and the South African Economy*. Pietermaritzbrg: University of Natal Press.

Vrieling, A., Meroni, M., Shee, A., Mude, A. G., Woodward, J., de Bie, C. A. J. M. and Rembold, F., 2014: Historical extension of operational NDVI products for livestock insurance in Kenya. *International Journal of Applied Earth Observation and Geoinformation*, 28, 238-251.

Waters-Bayer, A. and Bayer, W., 1992: The Role of Livestock in the Rural Economy. *Nomadic Peoples*, 31, 3-18.

Weideman, M. 2004. Who Shaped South Africa"s Land Reform Policy? *Politikon*, vol. 31, no. 2, pp. 219–238

Williams, B., Mayson, D., De Satge, R., Epstein, S. and Semwayo, T., 2008: Extension and smallholder agriculture: Key issues from a review of the literature. First Draft. Phuhlisani - clear thinking for change.

Wnuk, A., Gorny, A.G., Bocianowski, J., Kozak, M. (2013). Visualizing harvest index in crops. Communications in Biometry and Crop Science 8 (2), 48–59.

Xue-Feng H, Huhua C and Feng-Min L. 2007. Econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology (RHSIT) in the semiarid Loess Plateau of China. Agricultural water management. 89. 243 – 250.

Yami, M., Begna, B. and Teklewold, T., 2013: Enhancing the productivity of livestock production in highland of Ethiopia: Implication for improved on-farm feeding strategies and utilization. *International Journal of Livestock Production*, 4, 113-127.

APPENDIX I: TECHNOLOGY EXCHANGE AND FARMER FIELD DAYS

Ntshiqo

Introductory meeting with local stakeholders

Initial engagement meeting involved meetings with traditional leadership as well as the local councillor with farmers, the local Department of Agriculture was held on 13 June 2013. This workshop explained the overall purpose of the project and the project objectives. The project was discussed by stakeholders and it was agreed that the project should proceed at Ntshiqo. Both farmers and local leadership stated verbal support for the project. This was followed by two multi-stakeholder workshops with community participants to explain the research project in detail and to identify farmers who would be interested in participating in the project. The first workshop was held for crop farmers to explain the principles of Rainwater Harvesting and Conservation (RWH&C) and provide farmers with insight into what the project was seeking to achieve.

In addition to engagement in relation to research trials, the project team also conducted interviews with individual farmers (crop and livestock) to understand existing production systems, current levels of productivity and socio-economic parameters.

Workshop with Eastern Cape Department of Agriculture – Tsolo Office

A participatory workshop was held with Agricultural extension officers at Tsolo Agricultural Research and Development Institute (TARDI) on 14 June 2013. The workshop was attended by extension officers and managers. The workshop focused on the principles of rainwater harvesting, design considerations and practical examples, where more detailed concepts of rainwater harvesting and conservation were discussed.

Farmers workshop to identify field research sites and participants

A workshop on Rainwater Harvesting and Conservation (RWH&C) was held with Ntshiqo farmers on 5 November 2013. After introducing the objectives of the research project, concepts of RWH&C for croplands were explained to project participants, as well as different rainwater harvesting techniques that could be used in croplands. Volunteers to participate in the field research were requested from the stakeholder group and six farmers were selected for field trials (2 Field crop farmers and four homestead gardeners).

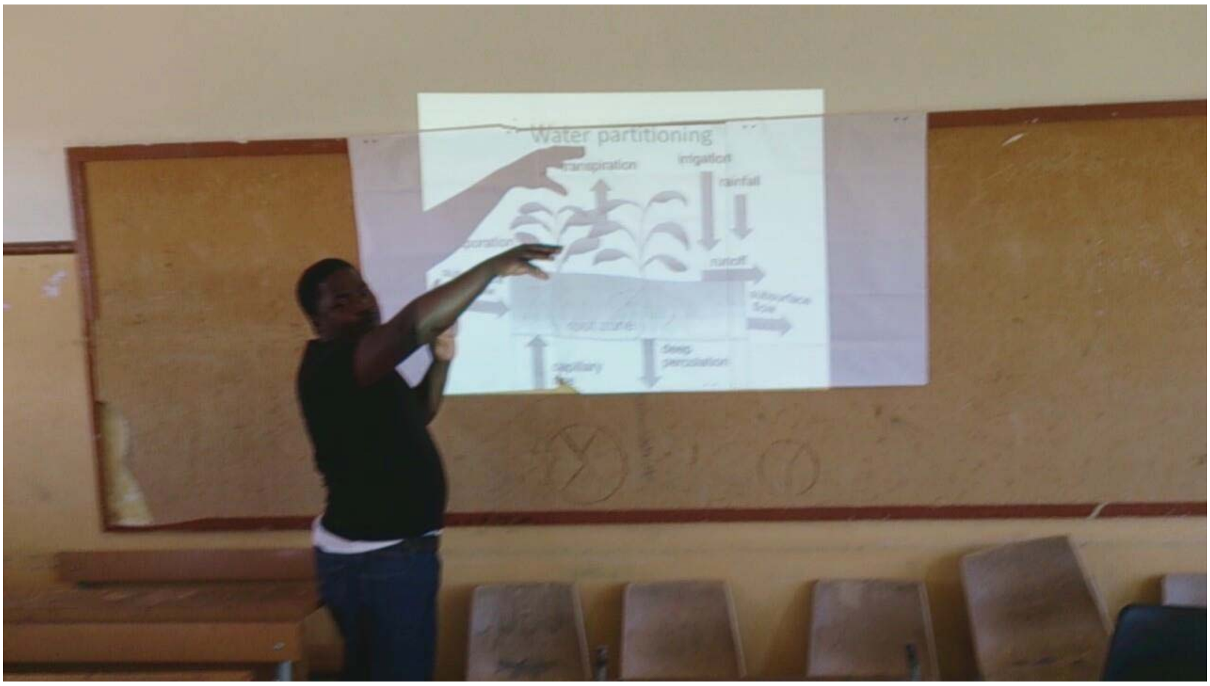


Figure: Introducing concepts of water use and rainwater harvesting in Ntshiqo

Introductory meeting with livestock owners

An introductory meeting was held with livestock owners who were interested in learning more about the project on 6 November 2013. A number of options to improve livestock productivity were discussed, including controlling stock theft, improved animal health, provision of additional watering points and improved grazing. The concept of rotational resting was introduced to livestock owners at this meeting.

Detailed meetings with livestock owners on rotational resting rangelands to increase rangeland and livestock productivity.

Two meetings were held with livestock owners to discuss and plan the introduction of rotational resting in communal rangelands at Ntshiqo. Meetings were held on 4 February 2014 and 26 February 2014, during which the benefits, requirements and institutional arrangements necessary for rotational resting to be implemented were discussed. Much interest was shown by livestock owners during these meetings and it was agreed that a working group should be established to take this forward. This will be discussed at an up-coming traditional leadership meeting to be held early in March.

Rainwater harvesting field demonstration day

A rainwater harvesting field demonstration day was held in Ntshiqo on 5 June 2014. The field demonstration day involved a visit to Mrs Quvile's rainwater harvesting demonstration site, followed by an interactive discussion at the local community hall. The event was attended by the local Department of Rural Development and Agrarian Reform, as well as local community members.

The purpose of the field day was to:

- Share farmers' observations of the different treatments and the knowledge they have gained through participating in the project.
- Provide other farmers in Ntshiqo the opportunity to learn more about rainwater harvesting.

The field day was also used to collect data on farmer's ideas on how to promote the wider adoption of RWH&C. This information was obtained through participatory discussions and through a questionnaire that was circulated to farmers attending the field day. The response to the field day was very positive and provided the opportunity for farmers to speak to local farmers who were enjoying yield benefits from RWH&C. That farmers were enjoying such benefits generated a lot of interest among farmers. Key points from the field day were that:

- Growing food was very important for farmers, but high summer temperatures and low (sometimes erratic) rainfall were highlighted as constraints to production by farmers.
- Farmers did not consider tenure security to be a factor influencing adoption of RWH&C.
- Extension was highlighted as a challenge; Department and extension staff are not highly motivated to support farmers, except through state-funded programmes and lack the skills to provide the necessary support (including in RWH&C).
- Farmers felt that RWH&C has higher land preparation costs and labour requirements, particularly in terms of controlling weeds in the spaces between the maize rows for runoff generation. Even in the face of higher inputs (Labour, land preparation), farmers perceived the benefits associated with RWH&C to be greater than the perceived extra costs. Overall there were positive sentiments in relation to RWH&C and a lot of interest in adopting the technology.
- To increase adoption, there should be focus on influencing state policy and programme development at Municipal, Provincial and National scale. Building capacity within the Department to assist farmers to establish RWH&C was also important while on-going demonstrations, training and support from the project was also highlighted as necessary for up-scaling and out-scaling.

Rainwater harvesting field demonstration and cross visit 07 May 2015

The second field demonstration day was held on 07 May 2015 the event brought together local farmers and ten farmers from Muden, KZN farmers. This cross visit provided the opportunity for KZN farmers to observe the production environment in Ntshiqo In addition, officials from the Department of Rural Development and Agrarian Reform (DRDAR), Ward Councillor, Inkosi Lutuka and Grain SA farmer representatives attended. Field studies were conducted of two cropping demonstration sites and the rotational resting demonstration was also visited. KZN farmers observed that the depth and quality of the soils were much better than their fields in KZN and were motivated to test rotational resting systems, having observed the standing grass available for winter grazing. At each site the presentation was done by the farmer hosting the trial with additional comments from the project team. At the end of the site visits, all participants converged into a local church to reflect on the field day. The project team facilitated the session based on what is working and not with regards to RWH&C, as well as what needs to be improved for the 2015/16 season. Farmers put more emphasis on the use of weed herbicides to minimize labour associated with weeding. Muden farmers participating in the trials also had an opportunity to share their experiences with RWH&C.

Livestock working group meetings

To implement the rotational resting demonstrations at Ntshiqo, as well as to manage other livestock / rangeland related matters (e.g. the livestock survey), a Livestock working group was established. In addition to the capacity building events held in February 2014, two additional capacity development meetings were conducted on 22 September 2014 and 27 October 2014 to build capacity to manage the grazing systems at Ntshiqo.

The meeting was held on the 22 September 2014 was to:

1. Appoint rangers to control livestock access to the rested areas.
2. Agree on how the implementation of the resting is to be communicated and enforcement
3. Conduct a field visit to identify area to be rested.

In the previous discussion, farmers indicated a wish to rest the same area every summer and not implement a quarterly resting system across the whole grazing area. The reason for this was that farmers felt that the condition of the veld in the remaining area (made up largely of old lands) was so poor that a rest would have little impact on animal nutrition. This equates to a continuous summer rest, rather than a rotational rest. It was pointed out to the LWG that this would mean that the high value grazing would only be grazed when 'sour' in winter, which is not a very effective way of using high value grazing. However, that was the final decisions at that meeting.

After much discussion, it was agreed as follows:

- The high value grazing area would be divided into two.
- One half would receive a full summers rest (Oct 2014 – April 2015)
- One half would be rested from Oct-Dec 2014 to allow partial recovery.

This also means that livestock will be forced to graze the old lands in the early growth stages, when they are more palatable.

An additional meeting was held on 27 October 2014 to evaluate progress with the first month of resting. A recap was provided of the purpose of the working group and the role of the office bearers, namely to monitor livestock and deal with livestock and rangeland related matters. The long term purpose of the working group is to become the organisation that represents the interests of livestock and rangelands at the traditional authority.

The issue of communication and enforcement of rules was queried. After much discussion, it was agreed that Mr Beya, the traditional council representative, would communicate the decisions taken at this meeting at the Traditional Authority meeting to be held on Wednesday 24 September 2014. Once this had been approved, Nkosi Luthuka would inform neighbouring communities through a letter. This information would also be communicated to the Ntshiqo community through the Traditional Council and the LWG. As far as enforcement was concerned, it was expected that this would not be a problem as the rangers would keep livestock out of the designated resting areas. It was highlighted that if any aggression was encountered from livestock owners regarding keeping livestock out of the designated resting area, rangers should not confront livestock owners, but withdraw from the situation and report the matter to the traditional authority. After the first month of working, it was realised that two rangers were not sufficient to keep livestock off the rested area and consequently, the number of rangers was increased to four.

Livestock and health workshop

On the 13th of August 2014, the Institute of Natural Resources hosted a capacity building training workshop for livestock farmers in Ntshiqo at Ntshiqo church near Tsolo. The purpose of the workshop was to provide farmers in Ntshiqo with an opportunity to learn more about different health and nutrition issues relating to livestock production and ask questions regarding some of the problems they face as livestock farmers.

The workshop was attended by representatives from the Institute of Natural Resources [INR] and UKZN. Two representatives from Zoetis (previously Pfizer, who sell animal health products) attended the workshop (Lunga Ludidi and Siya Mahlangabeza) and spoke on animal health. A representative from Molatek (Wapi Zandisile) was also present to speak on animal nutrition. Representatives from Tsolo Department of Agriculture were also present (Mr Nongcawula and Miss Gushumpu) The workshop was well attended by livestock farmers in Ntshiqo, making a total of up to 67 farmers present. The newly elected Chief of Ntshiqo, iNkosi Lutuka also attended the workshop and expressed his words of gratitude and appreciation for the work that the INR was doing in the area.

Mr Lunga Ludidi from Zoetis then gave a talk on animal health, focusing particularly on internal parasites (worms), including the causes, symptoms and some of the medications that can be used to treat the different types of worms that affect livestock. The farmers were very impressed by the presentation and had a good discussion with Mr Ludidi on some of the points he raised in his presentation and took notes. The presentation was followed by a talk from Mr Wapi Zandisile from Molatek, who spoke on different supplementation feeding mechanisms that farmers can use, particularly during the winter season. He spoke in great detail about Master 20 which is a lick that can be used on cattle, sheep and goats and helps to increase the growth rate of the animals as well as improve body condition, conception and lambing percentages of the animals.

The farmers enjoyed the workshop, for some it was the first time they received formal training on livestock management. The farmers got the opportunity to purchase livestock medication from Zoetis and were very happy about the workshop

Muden

Engagement with local stakeholders to secure research sites

Initial engagements involved meetings with Indunankulu Zakwe of the Mchunu Traditional Authority in August 2013. During these meetings the purpose of the project was explained to members of the Traditional Authority and permission was sought to conduct research in the area. It was explained that the project was looking to conduct research in fields, rather than smaller homestead gardens and based on this, three sites were suggested. These were Fabeni, where a large area is fenced off for cropping purposes; Mxheleni, where and area has been fenced for a women's group that farms collectively. The third site suggested was the Indunankulu's field located adjacent to his homestead. In the spirit of building good relationships, it was agreed to test the research in one of Indunankulu's fields, in spite of the soils being very shallow (<400mm). Once the team had engaged with the relevant groups (Fabeni and Mxheleni), a meeting was held at the Traditional Court, where the project was introduced to iNkosi Mchunu. Workshops were then conducted with Mxheleni and Fabeni farmers to explain the concepts and principles of Rainwater Harvesting and Conservation. At the workshop, the research objectives were explained and the requirements of the farmers to participate were detailed. These included the project would assist with inputs (land preparation, seed and fertiliser) and that farmers would need to commit to ensuring that fields are well managed, properly weeded and livestock excluded.

Introductory meeting with local stakeholders

A stakeholder workshop was held on 7 October 2013 to describe and explain concepts of water harvesting and conservation to project participants, to describe different rainwater harvesting techniques and to provide the project participants the opportunity to select the rainwater harvesting techniques that they would like to test in their fields.

In addition to engagement in relation to research trials, the project team also conducted interviews with individual farmers (crop and livestock) to understand existing production systems, current levels of productivity and socio-economic parameters. Meetings were also held with livestock farmers to better understand their production systems and key challenges they faced in terms livestock production, considering in particular the project objectives of livestock water productivity.

Introduction to contour farming

Participatory contour marking exercises using an A-Frame and a Dumpy level on occurred on 8-10 October 2013. Here, the principles of contours were explained and farmers were shown how to use an A-Frame to mark and build contours. The Dumpy level was also explained, and was used to mark contours on farmers homestead gardens.

Cross Visit to Bergville

Farmer from the Muden project sites also participated in cross visits to Bergville on 14-15 October 2014, where various household rainwater harvesting systems and no-till systems were demonstrated.

Mxheleni farmers day

On the 26th of March 2014 the Institute of Natural Resources (INR) held a farmers' day at Mxheleni in Muden. The aim of hosting this farmers' day was to show farmers in the Muden area (Fabeni, Nxamalala and Mxheleni) the outcomes of the Rainwater Harvesting (RWH) trails at Mxheleni, and to provide farmers and other stakeholders with the opportunity to learn more about rainwater harvesting. Present at the farmers' day were representatives from the INR, Mdukatshani, Heifer International SA and the Department of Agriculture. Farmers from Nxamalala, Fabeni and Mxheleni were also present at the field day.

A background on the trial objectives and trial designs was provided by Mr McCosh. This was followed by the farmers being taken for a walk through of the trials at the Mxheleni fields to make observations and discuss their observations. Farmers participating in the trials also had the opportunity to share their experiences.

Some of the farmer's observations of the trial as well as some general comments that emerged from the discussions are provided below:

- Mr Zakwe the iNdunankulu from the Nxamalala area observed that the contours at Mxheleni were bigger compared with Fabeni and therefore allowed for better storage of water in the soil. He also stated that the Mxheleni fields are located in a more open area and that the Mxheleni area receives more mist than Fabeni and Nxamalala.
- Mr Mlisa from the Fabeni area stated that the difference he observed was that the Mxheleni group has good, strong contours because they added stones to their contours to build them up more. Mlisa also stated that for the farmers at Fabeni, weeding was another major constraint.
- MaPro from the Mxheleni area who is the leader of the Mxheleni Women's group expressed her gratitude to the project and pointed out that it had introduced it to them to a new farming technique. She also pointed out that the Mxheleni group worked together and removed weeds early, before they became a problem. She suggested that adopting the practice of early weeding may help the farmers at Fabeni to better control their weeds.
- In terms of a way forward in the upcoming year all farmers agreed that they should experiment with bigger stronger contours, either by adding stones onto the contours (like the Mxheleni farmers have done) or by adding grass or organic debris to the holes that are dug when the contours are made in order to strengthen the contours.
- The farmers also mentioned the importance of the timing of the planting in the next season. Planting on time will help them take advantage of the early summer rains, so as to avoid germination delay. The issue of weeds was also mentioned, that farmers are

quite lazy to remove weeds off the runoff areas, they have even considered using herbicides.

Representatives from the Department of Agriculture expressed their gratitude to the INR for introducing this RWH&C concept to the farmers as they were able to see the impact of the project on the maize at Mxheleni. They also asked for the INR to assist them (on request) where they may need assistance in terms of starting off with this RWH&C initiative in other areas within Msinga.


Members from Mxheleni Women's Group during the field day Jon McCosh and Nokulunga Gasa listening to comment from Mr Shelembe

<u>Presentation and Msinga food security fair</u>

For two consecutive years (August 2014 and 2015) , the INR project team had been invited to share project results in the annual food security event hosted by Farmers Support Group – an NGO that supports women farmer groups in Msinga. The aim of the event is to allow the sharing of information from respective stakeholders working in Msinga and to raise awareness about food security and emphasis on growing nutritious food. In August 2015, the project team presented a poster to the event with research results and challenges. The article on the presentation was further published by Isolezwe newspaper in isiZulu. The project further team facilitated individual and focus group discussion with farmers participating to ascertain constraints and opportunities to the adoption of RWH&C. The purpose was to identify technical, social and institutional challenges and ways to overcome these. Given that there was crop failure, the research team sought to understand what would be required for outscaling by evaluating constraints to production and potential solutions. The major constraint highlighted by farmers was lack of rainfall, particularly in the most critical stages of the crops growing season. The outcomes of the FGDs revealed the following:

- Farmers indicated that because growing food is important, they want to achieve high yields and they need to be capacitated to identify constraints and develop innovative practices in their farming systems.
- In Mxheleni some of the communal garden group members have started to build contour ridges using stones in their individually demarcated vegetable plots for the purpose of

harvesting water. This is because they have seen benefits in the stone contour bunds that were established in their maize cropping area.
- In Fabeni some farmers are planting on raised beds and applying a layer of mulch for moisture conservation in their communal vegetable garden.
- Farmers acknowledge that RWH&C with contours required more labour and is expensive, but it does contribute to increased crop yield and more stover for livestock.
- RWH&C, coupled with installation of jojo tanks at household level and some communal gardens should be considered.

2014/2015 has been a most difficult year for farmers. There has been no yield from the cropping fields in general. Soil moisture analysis suggested that RWH&C improves soil water content. However, since the area is drought prone, farmers highlighted that drought resistant OPV maize seeds are preferred. Farmers were all in agreement that the major constraint to production is shortage of water. Apart from what has been tried in terms of RWH&C, and while maize is the preferred staple crop, farmers felt that it was time to consider other more drought tolerant crops. The limited quantity of maize stover for the winter grazing period was a major constraint for the farmers and they see a need for long-term solution to this problem. They also felt that fodder crops should be planted for livestock feed. The results from the FGDs suggested that farmers have acquired knowledge on the importance of water conservation, using contours and other practices such as planting in raised beds and mulching. Farmers participating in the demonstrations continued to show interest and commitment to RWH&C, even though no real benefits have been achieved to date.

Livestock supplementary feeding

A meeting was held with livestock owners' participating in the livestock survey in Muden, with the view to solicit their perspective in view of drought and how it affects livestock production. After an in depth discussion with farmers, the project team presented the plan of intervention to introduce supplementary feeding over a period of winter months (June to September 2015). Farmers were provided with low quality hay bales with the feed additive LS33, to increase palatability and nutrition. Body condition scoring (BCS) were being evaluated to determine whether cattle receiving supplements are benefiting, when compared with the general herd (no supplementation). Four farmer representatives from Muden and Ntshiqo attended Body Condition Scoring (BCS) training at Cedara facilitated by the Department of Agriculture together with the project team in preparation for the feeding months. Farmers have indicated that they have noticed improvements in body condition.

Rainwater harvesting field demonstration and cross visit 17 February 2015

Five farmers from Ntshiqo, accompanied by a local facilitator, travelled to KZN to attend a farmers' day arranged by GrainSA near Winterton on 17 February 2015. The farmers' day was also attended by participants from Muden, KwaZulu-Natal. The farmers' day was focused on conservation agriculture (CA) and cover crops (CC). The CA practice involved a dense planting of maize intercropped with beans, cowpeas or dolichos. A number of manual and animal-drawn tools and implements were also demonstrated. The group from Ntshiqo spent the night at Msinga at the home of one of the RWH&C farmers to allow them to visit the KZN site before returning to E.Cape. The visit to the Fabeni site was interesting in that the maize in the RWH&C treatment was looking much better than the control, which was looking very water stressed. The Msinga farmers felt that the crop looked promising. The E.Cape farmers were very interested in the Teppary beans (Umcugwane) that the farmers were planting between the maize rows. They also pointed out that weeds were seemingly less of a problem at Msinga but the farmers said this was only because they had weeded early before the rains fell. The group from E.Cape extended an invitation and willingness to host a visit by the Msinga farmers.

Participatory evaluation sessions

Participatory evaluation sessions were conducted with farmers at the conclusion of the research project. Final feedback from the farmers who participated on the rainwater harvesting project at Muden, KwaZulu Natal and Ntshiqo, Eastern Cape is provided. various training and capacity development activities were discussed with the livestock groups and the cropping groups. The livestock group was given training regarding rangeland management and animal husbandry. Experimentation on rotational resting using exclosures and herders was undertaken. The livestock work also included herd structure monitoring as well as winter supplementary feeding. The cropping group was involved in the implementation of RHW&C Most households in these areas have homestead gardens and cropping fields far from homesteads. The RWH&C was implemented as farmer experimentation in order to involve the farmers in the process. At Muden, there was Mxheleni women's group farming as a collective where IRWH was implemented in their garden and two farmers (Mr Xoshimpi Zulu and Mr Mntungani Zulu) from Fabeni where RWH&C was implemented in their fields (amasimu). At Ntshiqo, five farmers were involved (Mr Sokhombela, Mr Beya, Mrs Quvile, Mrs Mjali and Mrs Dosini) and RWH&C was implemented in their homestead gardens. Prior to the final evaluations, guiding questions were developed with the purpose of guiding the discussions with the farmers. Since the project consists of both the cropping and the livestock elements, the questions were developed to suit each element.

Outcomes of Muden participatory evaluation

This section outlines the outcomes of the evaluation sessions held with the group of farmers from Muden at Fabeni and Mxheleni village. These groups have been involved in the RWH&C project from 2013 to 2015. The main focus of the Fabeni group was on livestock, where 16 farmers took part into monthly livestock surveys that were aimed at gathering information regarding their livestock management practices. There were two farmers who participated in the cropping experiment, Mr Xoshimpi Zulu and Mr Mntungani Zulu. At Mxheleni, the project engaged with Mxheleni Women's group and the main focus here was cropping. These farmers are farming in a communal garden where they allowed a portion of their garden to be used for RWH&C demonstration.

Ranking and scoring results with Mxheleni Women's group

The participants were introduced to the ranking/scoring methodology to be followed to allow for an in depth discussion of the project results, and what lessons do they hope to take forward collectively. The criteria were outlined to evaluate the outcomes of the experimentation process from 2013 to 2015. On a scale of 1-5, the participants had to discuss what worked and what did not work with RWH&C compared to the traditional way of farming. The ranking was done using stones, and farmers were given 20 stones for the exercise, and selected one member to do the ranking on the flip chart paper.

- **Ranking and scoring results in Muden**

Criteria	**Treatment**	**Control**
1. Yield	4	1
2. Weed control/management	3	1
3. Labour requirements	1	3
4. Moisture retention	4	0
Score	**12**	**5**
Rank	**1**	**2**

From the discussion, the general view of the farmers showed that they understood that the project investigated the rainwater harvesting with the intention to conserve moisture. Farmers saw a huge difference in yield on the maize harvested from the contours, the cobs were big and there was more than one cob per plant. For the two consecutive years (2013/14) there was no yield on the control side because of very high temperatures and limited rainfall. Farmers only started seeing yield on the control in 2015, only because there was a bit rainfall. During the ranking exercise it was clear that contours met three out of four elements of the criteria (Yield, weed control and moisture retention). However, it was highlighted that contours are labour intensive. The argument between farmers was that building contours is labour intensive, but at the end it's the yield that matters resulting in meeting the consumption needs of a household and income generation.

Farmers observed that in contours weeds were fewer when compared to the control, and plants in contours were less water stressed when compared to those in the control. When asked about the costs associated with building contours, farmers indicated that RWH&C with contours requires one to have enough money, the costs of hiring a tractor and building contours with stones you have to hire people to help collect the stones, and put them accordingly. The farmers were advised that they are lucky they can build stone contours, which are more permanent. Soil erosion was our biggest challenge; through RWH&C we have learnt how to minimize erosion, not only in our garden but at our individual households.

Evaluation sessions with Mxheleni Women's group

Key lessons and ideas for RWH&C technology forward

When asked about the next steps based on the lessons mentioned above, the farmers mentioned that they came to a decision to demarcate the garden into small plots because working as a group in one common plot is very challenging. Going forward, they might have to discuss how they are going to work in the common plot- now that the research has come to an end. Other group members said plot demarcation is the best way to ensure continuity in the communal plots, and it will be up to an individual's how they maintain the contours. The existing contours will not be destroyed.

They have seen the benefits and value of RWH&C, but the challenge remains the financial and institutional barriers to the adoption of the practice. Farmers mentioned that in 2013 when RWH&C was first implemented, they obtained a lot of produce as a result, and were able to generate income from the communal plot. The money was saved in the groups account to help buy inputs in future, however, due to financial challenges at homes they ended up sharing the cash.

Rangeland management systems in communal areas – Muden

Farmers were asked to share what is working as well as challenges in communal grazing. In Fabeni, the livestock owners approached the Traditional Council to ask for land for grazing. The land (currently used for cropping) was given to the community for both cropping and grazing purposes; the biggest challenge is lack of fencing which makes it difficult to apply the basic rangeland regulations such as restricting access to livestock during resting. When the farmers undertook a learning visit to Ntshiqo in 2015, they saw a well-managed communal grazing system that seems to be working. At Msinga, the livestock owners still need to be educated on the basic principles of grazing and rotational resting. Community members do not think it is a problem to keep unproductive animals. Opportunities for livestock marketing exist but small scale livestock owners do not see this as an opportunity to generate income. Platforms such as auctions are not fully utilised because farmers say they get a better price if they sell livestock on their own. Participants report that if they could get enough fencing material, they would divide the rangeland into three compartments. Furthermore, within the rangeland, they would build dams to make sure that livestock doesn't travel far to access water. The participants noted that this would require strong leadership, community organization and financial resources. The livestock already have a committee that is responsible for putting together proposal for funding requests and so far the farmers think this initiative will get them where they want to be.

During the supplementary feeding, farmers learned that animals have different food requirements. The females/cows require more food in winter because they are either pregnant or lactating. They also learnt about body condition scoring and some farmers still use this as a guide for which animals to feed. Msinga and the rest of the province experienced high livestock mortality due to drought, and there is a lesson to be learnt. The animals did not die only because there was no grazing, but water as well – as the rivers and reliable springs/streams ran dry. The monthly data collection done for the duration of the project made farmers realise the importance of knowing the herd structure of your goats or cattle, so that they can decide which animals to sell and which ones to keep. Mr Shelembe's key lesson is the importance of selling livestock because that reduces pressure if grazing is not sufficient.

Evaluation session with livestock owners in Muden

Focused Group Discussions (FGDs) have been facilitated with farmers where Participatory Rural Appraisal (PRA) tools have been employed to engage farmers into meaningful discussions. Participatory evaluation sessions have also been conducted at the end of the crop growing season to ensure that farmers are able to evaluate the outcomes, understand the experimentation process and effective participation in research. Discussions focused on what works, and such sessions have also been used to identify areas of improvement for the following season. Interviews with key informants, local Traditional leaders, and government representatives have also been conducted to give an overview of the farming systems, opportunities, challenges and possible areas of intervention.

Participatory evaluation sessions in Ntshiqo

The first cropping meeting held on the 10th of August 2016 and it was attended by four farmers (Mr Beya, Mr Sokhombela, Mrs Mjali and Mrs Quvile). The farmers spoke very highly of RWH&C. They are keen in adopting RWH&C and practice in their home gardens. Respondents were asked about the cropping constraints they had before the project commenced and the following responses were recorded:

The planting inputs such as fertiliser, seed and land preparation were listed as constraints. The emphasis was mostly with fertiliser. Farmers perceived that the project came with a different type of fertiliser because their yields improved dramatically. They used fertiliser before but they didn't get high yields. Participants also noted that there were irregularities with climate - it was getting hotter and rainfall was becoming more inconsistent.

Mrs Madosini was visited at her home; she revealed that she thought that the project brought great improvements into the productivity of her garden. She also mentioned that inputs were an issue before the project came, but when she was part of the project, she didn't worry about seed, fertiliser or land preparation. She indicated that it would now be worse because her husband had passed away and they would not have sufficient funds to meet their household needs and to buy inputs and prepare the land.

Mr Beya: Planting in contours improved our yields because moisture was stored along the contours. The maize obtained from contours has big and healthy cobs. Although with contours, the spacing is wide, you are certain to get yield. when you shell one cob harvested from contours, you can fill two cups compared to one cup from a broadcasted field. The plants bear two to three cobs per plant, the kernel rows are 10-14 and the kernels themselves are big.

Mr Sokhombela: With broadcasting you get high plant density but the plants are thin and small whereas with contours you get thick plants with big cobs.

- **Ranking and scoring results in Ntshiqo**

Criteria	**Treatment**	**Control**
1. Yield	5	3
2. Ease of weed control/management	2	2
3. Labour requirements	2	5
4. Moisture retention	5	1
Total	**19**	**14**
Rank	**1**	**2**

Discussion based on the ranking results

- **Yield**

The treatment was given a score of 5 by the farmers. Yields of the treatment were greater than those of control. Each plant had 2-3 cobs. The cobs were big and had 10-14 kernel rows. High grain yield was found in the treatment (e.g. 2 cups full of grain produced by one cob). The control was given a score of 3. Yields in the control were relatively low. Cob sizes were small, and had less than 10 kernel rows. The plant would bear one cob and if it produced two cobs, the second cob would have few grains.

- **Weeds**

Both treatment and control were given a score of 2. The farmers reported that there wasn't much difference between the treatment and the control with respect to weeds.

- **Labour requirements**

Farmers reported that the treatment is labour intensive; therefore they gave it a score of 2. Farmers reported that during the past three years they have tried three ploughing methods (using a tractor, using the 'mule – animal traction and by hand). All of these methods required substantial labour, time and cost. High labour is also to maintain contours. The control was scored 5 because the tractor comes and ploughs and then they just broadcast the seed, very minimal labour.

- **Maize stover for livestock grazing**

The treatment was given a score of 5, as the plants from the treatment are taller and have a thick stem. Animals were able to graze the stover for a long time and provided high dry matter. (Example made by Beya: Two maize stovers from treatment chopped and given to one sheep. The sheep would eat and get full for many hours of the day. Whereas you would chop four plants from control and feed them to one sheep, it will eat but will quickly come back for more, and therefore the control was given a score of 3.

- **Moisture**

With regards to moisture, the treatment was scored a 5. They reported that the soil retained high moisture and the soil remained moist for a long period of time. This was observed on hot sunny days as well. Control was given a score of 1, as there is very minimal moisture retention in the soil.

The results of this exercise revealed that RWH&C is the most preferred practice, however, there are challenges associated with it and most of these challenges contribute more to the adoption of the practice.

Discussion with the key informant Mr Tshabu

The RWH&C has good benefits of retaining water along the contours. The practice can be adopted and upscaled to the fields. Mr Tsabu said he will also consider implementing RWH&C in his fields especially since the rainfall is erratic, RWH&C might come in handy. Mr Tshabu is a well-developed farmer and he said the reason why he's confident in saying he will consider the IRWH, is because he can hire people to prepare the contours.

Mr Tshabu mentioned that financial support from Department of Agriculture is required to buy fence to create camps. He said the project provided him and the community valuable information about rotational grazing and resting, and he wants to continue with it and help other farmers in the area. Mr Tshabu has requested financial and technical support regarding fencing from the Department of Agriculture and is awaiting response. Traditional authority does not provide any support or instructions with regards to rangeland management.

Mr Tshabu does not think the community of Ntshiqo can adopt RWH&C because they don't want to spend money, they don't understand the principle of selling livestock to buy inputs. They always expect the government to provide them with resources. He said with respect to outscaling; more training to create awareness is needed. Mr Tshabu is aware of spring burning and its importance for veld rehabilitation. However, in the area it is not done properly. Anyone does it in their own time and they don't consult the community prior to burning.

Communal rangeland management systems in Ntshiqo

The key challenge is that communal grazing areas are shared among the community and people don't always see things the same. For example during the time of the rotational resting experiment, people would secretly graze their livestock at night because they couldn't wait until the camp was open. The other example made was with the fence that was provided to fence the cropping fields, some people in the community steal it although they see and know the benefits of having fenced cropping fields. The farmers would have meetings and agree on confronting these people, but due to lack of enforcement of local rules no one would take charge and confront these people.

Some farmers in the community lack knowledge and understanding of rotational resting. As a result they get impatient and end up fighting, wanting their livestock graze in the field even though the grass hasn't grown big enough.

Impacts of rotational resting

The introduction of rotational resting was an eye opener; we saw a great improvement in our livestock. One mistake that happened was that the camp was closed for too long, the grass got too old, but project provided the supplementary feed and the animals were grazing on the old grass anyway. The farmers also highlighted that rotational resting was not a new thing, it used to be practised when they were young and as time went by, kids went to school hence there was no one to herd the cattle. Mr Beya even said, but even then they knew the rules, but if they felt that their cattle were not satisfied, they would secretly graze them in restricted camps. So this was to emphasize the fact that not everyone in the community would follow the rules which are meant to help them in the long run.

The farmers also mentioned that they would meet as a livestock association to discuss and agree on certain rules like for example closing of the camp. But the kids at home, who are responsible for herding the cattle, would do their own thing. Ms Ntombela asked if the farmers don't think maybe the headers should also attend these meeting so that they can understand the importance of these rules. The answer to this question was that they have not thought about it in that manner. However, farmers highlighted that farmers can be farmers in the meeting, but their abilities to instil rules at home as parents is different.

Support required to take this forward

Technical support in the form of workshops is required for all farmers in the community not just few people who participate in the project. Financial support would also play a big role as we have said that we think fencing would make things easier since we can't afford to appoint rangers. We have approached the Department of Agriculture to request fencing material but we haven't has luck with that. Mr Nongcawula was asked to step in and clarify where the problem might be with the proposal.

He responded by saying that the government has projects that it implements in communities to empower them, same thing applies with this project. What is required from the community is to adopt and take that initiative forward. The purpose of these projects is not to support people forever but to capacitate them and leave them to find ways to take the initiative forward. He made an example that since the fence is so expensive, if the farmers are serious about rotational resting, they can device means to appoint rangers. He also highlighted that the resting system is not new in this area, it used to happen and it worked during the times of the old government, where the Traditional Authority took orders from the courts and made sure that people follow these orders.

Benefits of spring burning and why is it not practiced

The farmers know about spring burning, but due to lack of control when burning, it is forbidden. Nongcawula added and said, burning used to happen well when it was facilitated by the Traditional Authority in the olden days. It would occur once in three years where there would be people tasked to make a **fire belt** around the village to prevent fire from spreading into the households, then the range lands would be burnt. This used to work very well because the TA was very strict and people respected the rules.

8.1.1.1.1.1.1 Importance of cropping fields in winter

The cropping fields are very important for our livestock in winter, we finished harvesting in June and now the cattle, sheep and goats are grazing there. The nice thing about these fields is that the grass underneath maize grows and by the time we done harvesting, there will maize stover and grass available for grazing and thus the livestock graze longer. They are most important especially during these times of drought, because as it stands the rangelands have very limited grazing capacity, so these fields supplement the rangelands.

8.1.1.1.1.1.2 Vetch and oat demonstration

The farmers who participated in the vetch and oats demonstration were few, but we saw the value of pastures when the government provided oats as a relief, we planted it in our fields and it made a big difference, there was food available even though the drought was so severe.

Mrs Mjali said she planted oats from the time beans were harvested from her garden and when it was ready, she would put her sheep in the garden to graze. This helped a bit but the area was too small and she has a big herd.

But they don't think that them as farmers can initiate the knowledge transfer. Even if I were to tell people about what the project has taught me, I would always reference the Jon/INR so that what I say would be taken seriously.

Mr Nongcawula: The information transfer in rural communities occurs when for example there is a traditional ceremony, wedding or umsebenzi, where people from other villages would come to a certain village and then if there is something that catches an eye; people would ask how they are doing such. Then people from that community can tell them about the certain practice that was introduced to them by Jon for example, and then if they really like what they see, they would seek more information and go back and practice it.

Conclusion

Outcomes of these evaluations revealed that introduction of RWH&C added value to the livelihoods of the participants. The adoption of rangeland management systems is dependent on strict enforcement of local rules. People in these areas still respect the rules given by the traditional authority; therefore getting the buy in from the TA would make a big difference with respect to adoption rangeland management systems. Youth's lack of interest in agriculture has impact in the adoption of sustainable agricultural technologies. The youth is more likely to adapt to new technologies whereas the old society do not adapt easily. Socio-economic factors such as population structure, household structure, age, health, governance and institutional capacity and income distribution and poverty have a significant role to play in adoption of infield rainwater harvesting and conservation.

APPENDIX II: KNOWLEDGE DISSEMINATION

Popular articles

Two popular articles for the project have been compiled. One discusses the cropping work at Ntshiqo, Eastern Cape and the second discusses that cropping work in Msinga, KwaZulu-Natal. The articles have been published in the following newspapers:

- A newspaper article highlighting the RWH&C demonstration in Muden was published in the Greytown Gazette on 11 March 2015, a local newspaper that includes the Muden area (website: http://www.greytowngazette.co.za).

- A newspaper article highlighting the RWH&C demonstration in Ntshiqo was published in the Mthatha Express which serves the area of the Eastern Cape where the Ntshiqo research site occurs on 8 October 2015 (website: www.mthathaexpress.co.za).

6 NEWS | MTHATHA EXPRESS | THURSDAY 8 OCTOBER 2015

Rainwater harvesting shows promise in Ntshiqo

REPORTER

FARMERS in the rural village of Ntshiqo, between Tsolo and Maclear, are working with the Institute of Natural Resources NPC (INR) to test rainwater harvesting techniques in their homestead gardens.

This participatory action research is part of a Water Research Commission-funded project entitled: "Up-scaling of rainwater harvesting and conservation on communal crop and rangeland through integrated crop and livestock production for increased water use productivity" (Project no. K5/2177/4/).

The project is investigating how rainwater harvesting and water conservation can improve crop and livestock water productivity.

Water productivity is a valuable tool for measuring how effectively water is used. It measures the total beneficial outputs in relation to the amount of water used. This is particularly important because South Africa is a semi-arid and water-scarce country.

"Rainwater harvesting is any system that collects and stores water; for example, a dam is a rainwater harvesting system, as is a roof water collection tank ('JoJo' tank)," says Jon McCosh, project leader, Institute of Natural Resources.

"The basic elements of a rainwater harvesting system are a collection area (for example, a water catchment or a roof top) and a storage area (a dam or a tank)," says McCosh.

With so many different techniques to choose from, the researchers sat down with farmers and discussed the different options available to them and selected the preferred technique in participation with the farmers.

The farmers chose contour rainwater harvesting, probably because this is what they are familiar with. Working with four farmers to start with, they implemented micro-catchment (in-field) rainwater harvesting and conservation. This means that the field itself is used to collect and store rainwater. Contours are spaced at two- to three-metre intervals on the slope. The space between the contours generates runoff when it rains. The water collects on the contours and goes into the soil, where plant roots can use it.

To test the effect of rainwater harvesting on yield, farmers divided their fields and planted a portion of the field the way they would normally plant (the control) and the other portion was planted using the rainwater harvesting technique. Results from the first year of research show promise.

Baweni Sokhombela, whose garden is 0.2ha in size, almost doubled his yields by introducing rainwater harvesting (440kg of maize compared with 264kg using his normal practice – this is equivalent to an increase from 1.2t/ha to 2.0 t/ha).

Gloria Quvile farms 0.3ha of land near her homestead. Her harvest from the control was 1 500kg, while her harvest from the rainwater harvesting treatment was 2 300kg. This is equivalent to an increase from 5.1 t/ha to 7.8t/ha, an increase of more than 50%.

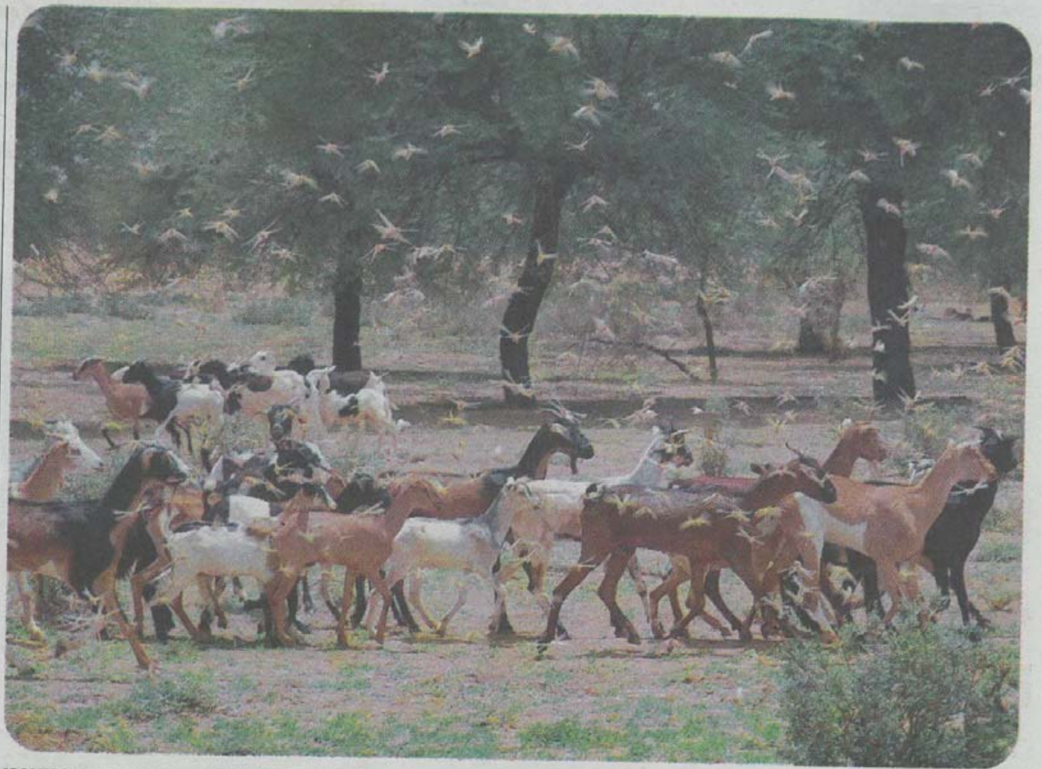
"Unfortunately not all farmers got good results. Weeding fields is difficult work and some farmers couldn't control weeds adequately, resulting in poor yields. At a farmers' day, successful farmers showed off their fields and shared their experiences with rainwater harvesting. This generated a great amount of interest with farmers and the farmers who did not get good results were encouraged to try again, said Mr Nongcawula of the Eastern Cape Department of Rural Development and Agrarian Reform.

"The results from the first year of research suggest that rainwater harvesting in fields can dramatically increase crop yields for farmers. By intercropping with fodder plants, soil health is improved and there is additional feed available for livestock in winter. Our research will continue to double-check that the results from the first year are repeatable," says McCosh.

Gloria Quvile (centre) shows off a cob with Mr Nongcawula of the Eastern Cape Department of Rural Development and Agrarian Reform (left) and Nokulunga Gasa of the INR. PHOTO: SUPPLIED

- In addition, an article was compiled by a journalist for the newspaper Isolezwe in August 2015, as a result of the Muden food security fair, which included discussion in RWH&C and livestock management

izindaba



ISOMISO sihlukumeza osomabhizinisi baseMsinga abaziphilisa ngokutshala nokufuya

'Ukufuya izimbuzi kufanele uMsinga'

PHILI MJOLI

UMA ungumlimi ofuna ukuphumelela eMsinga kumele ufuye izimbuzi ngoba amadlelo akule ndawo awasekho esimweni nemifula ishile.

UNksz Zanele Shezi, ongumcwaningi esikhungweni i-Institute of Natural Resources, uthe sekuwunyaka wesine benza ucwaningo ngezindlela zokugcinwa kwamanzi kule ndawo.

Lolu cwaningo luholele ekutheni kube nophiko oluzobheka ukuthi imfuyo ingasimama kanjani.

Okuhlalukayo kulolu cwaningo oluqalwe ngo-2013 oluphela ngo-2016 ngukuthi okwamanje umlimi angasimama uma efuya izimbuzi ngoba utshani obukhula emadlelweni akule ndawo kabanele ukuthi kudle izinkomo ezikhona.

Kule ndawo isomiso siqale ngaphambi kokuthi sihlasele kwezinye izingxenye zaKwaZulu-Natal ngo-2014.

"Ngesikhathi siqala ukwenza ucwaningo sibiyele amadlelo, sawehlukanisa. Kunendawo evulelekile ukuthi imfuyo idle udede kuyo, kube nendawo ehlelelwe ukuthi ivulwe uma kuqedwa ukuvunwa kuphela nokuhlelwe ukuthi ingavulwa nhlobo ukuze kuqhathaniswe ukukhula kotshani," kusho yena.

Imiphumela yesikhashana uthe ikhombisa ukuthi utshani endaweni evulelekile abusakhuli ngenxa yokuthi buthi bumila izinkomo zibudle, endaweni evulwa kanye ngonyaka nakuleyo evaliwe abukhuli ngendlela okumele ukuthi bukhule ngayo.

"Lokhu kubeka engcupheni umkhakha wezolimo wokufuya izinkomo nezinye izilwane ezidla utshani. Izimbuzi zidla utshani nezihlahla okwenza ukuthi isimo sazo sibe ngcono uma siqhathaniswa nezimbuzi," kusho yena.

Uqhube wathi zingu-2 000 izimbuzi ezifuywe wumphakathi abenza ngawo ucwaningo.

Lezi zindawo ziba nokudla kwezimbuzi okungamathani ayisishiyagalombili ngonyaka. Izimbuzi ezikhona zidinga u-1.3 wamathani njalo ngonyaka.

Uma kungena ihlobo uthe bazoqhubeka babheke ukuthi uma kungena ihlobo ukhona yini umehluko ozobakhona ekukhuleni kotshani.

Okunye okubhekwayo wukuphakela izinkomo utshani obuthengwayo.

"Le ndlela sisayihlola ukuthi ingasebenza yini emphakathini wasemakhaya sibheke nokuthi kudingeka amabheyili amangaki otshani.

"Kubalimi abatshalayo babheka uhlelo lokuthi kufakwe ubuchwepheshe obuthile obuzokwenza ukuthi amanzi okuniselwe ngawo izitshalo ahlale enhlabathini umswakama ungashabalali uma kufika ilanga noma umoya," kusho yena.

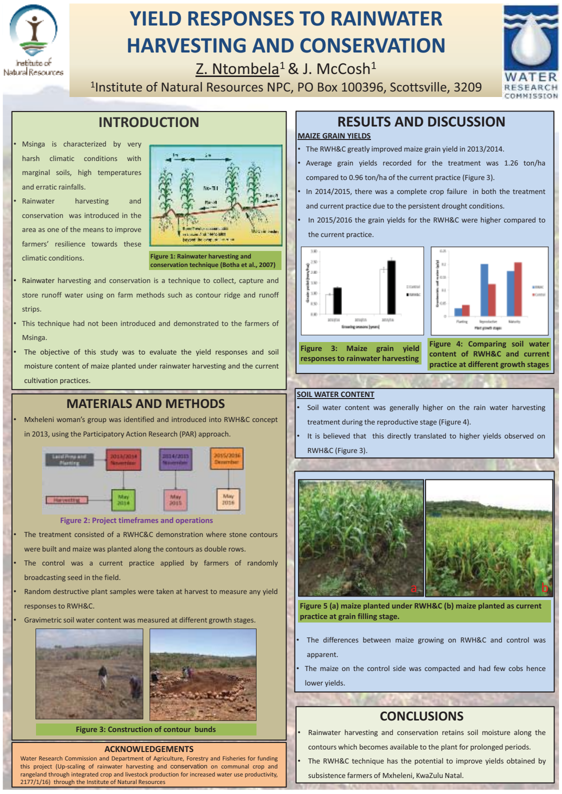
Ukunisela okujwayelekile uma kunesomiso uthe akusebenzi ngenxa yesivuvu esiphuma enhlabathini esiholela ekutheni uma kufika ilanga kushise, kufane nokuthi kuniselwe ngamanzi abilayo.

Yingakho kwenziwa ucwaningo ngokufaka lobo buchwepheshe.

Poster presentations

Two poster presentations were made at the Combined Congress held at Klein-Kariba, Bela Bela (Limpopo province), 23-26 January 2017.

Poster presentation by Mr Mdu Khuzwayo



Poster presentation by Ms Zinhle Ntombela

Papers

Two journal articles are being prepared.

1. The first paper explores the potential benefits and impacts of a long rest on heavily grazed mesic grasslands in communal areas. This will be submitted to the African Journal of Range and Forage Science. The published article will be sent to the WRC, once it is approved for publication
2. The second paper's working title is: The impact of rainfall and other climatic conditions on rainwater harvesting effectiveness on soil physico-chemical properties and crop yields: A case study in Ntshiqo village in Eastern Cape and Msinga Village in Kwa-Zulu Natal, South Africa. The published article will be sent to the WRC once it is approved for publication.

APPENDIX III: CAPACITY BUILDING

Student name	ID Number	Registered Degree	Thesis Title	Contribution to report	Status
Lynton Dedekind	911123 5070 08 9	Honours	Biophysical considerations for the implementation of rainwater harvesting techniques at micro-catchment scale for sustainable crop production: a case study of three sites in Muden/Msinga, KwaZulu-Natal, South Africa	Section 2.5	Degree awarded
Abstract Droughts and rainfall variability have the potential to increase the vulnerability of people especially in areas where smallholder dryland agriculture is the main activity utilized to sustain livelihoods. The implementation of rainwater harvesting and conservation (RWH&C) techniques, which is the collection, conveyance and storage of rainwater for domestic and agricultural purposes, has been found to reduce such vulnerabilities. This research investigates the suitability of implementing different on-farm micro-catchment RWH&C techniques in relation to biophysical considerations for smallholder agriculture at three study sites within the Muden/Msinga area in KwaZulu-Natal. A plethora of published literature was critically reviewed to determine the state of RWH&C initiatives at an international and local (South Africa) scale. The study then utilised quantitative methods in assessing the various biophysical factors (namely soil, gradient, aspect, climate) at the respective study sites. Soil samples were collected to determine depth and soil texture by utilising the volumetric soil dispersion method, whilst map outputs were created in Geographic Information System (GIS) for topographical purposes. A suitability analysis was conducted to determine what techniques would be suitable for implementation in the three study sites. In addition to biophysical factors, social factors and considerations were included in the suitability analysis. The results of this research suggest that despite these smallholder agriculturalists existing in extremely harsh environments, certain RWH&C techniques are applicable for improved crop production. The techniques include contour stone bunds and contour bunds and ridges, as these are most appropriate in relation to the biophysical and social considerations of the study area. The findings of this study may become a motivating factor for the implementation of other RWH&C techniques by dryland farmers in the area and elsewhere in South Africa. The identification of potentially suitable RWH&C techniques for different regions may improve agricultural activities in smallholder dryland communities and secure livelihoods across South Africa. **Keywords:** Rainfall variability, vulnerability, rainwater harvesting and conservation (RWH&C) techniques, smallholder agriculture, micro-catchment, biophysical, dryland.					

Lynton Dedekind	911123 5070 08 9	MSc	Investigating Livestock Dynamics in Relation to Livestock Water Productivity in Smallholder Mixed Crop-Livestock Systems: A Case Study of Ntshiqo in the Eastern Cape	Section 3.3, 5.7	Degree awarded

Abstract

Livestock provide net benefits such as food production (milk, meat), raw materials (wool), draught, manure, cultural practices, income and investment, and can improve the resilience of smallholder mixed crop-livestock farmers in developing countries, against external vulnerabilities such as water scarcity and climate change. A Livestock Water Productivity (LWP) framework represents ways to increase livestock production and benefits derived from animals without depleting water resources or causing environmental degradation for smallholder mixed crop-livestock systems. It is comprised of technical interventions (feed, water and animal management), supportive institutions and enabling policies. The research focuses on the technical feed management component of the LWP framework, in relation to livestock production in Ntshiqo, Eastern Cape. Sourveld regions in South Africa generally experience forage quantity and quality deficiencies during winter. The impact of a 17 month rest (exclosures versus grazed areas), a short (Oct 2014 - January 2015) and a full (Oct 2014 - June 2015) summer rotational resting experiment, on forage quantity and quality (Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF), Crude Protein (CP) and Phosphorus (P)) were tested. Additionally, the influence of a protein lick on the body condition of sheep during the winter months (June - September) was tested. A significant difference ($p<0.05$) in forage quantity was found between the exclosures and grazed areas, and the short and full summer rest. No significant difference ($p>0.05$) was evident in the forage quality between the exclosures and grazed areas. There was a significant difference between the ADF values of a full and short summer rest, whilst no significant difference was evident between the other feed quality variables. The protein lick had a significant ($p<0.05$) positive effect on the body condition of sheep over winter. Fodder crops (vetch and oats), were a viable additional form of supplementary feed to improve forage quality and intake. Smallholder farmer perspectives were obtained from Focus Group Discussions (FGDs), which informed and supplemented the results of the technical feed management interventions. Additional alternative management interventions (burning, re-seeding) are proposed. Technical interventions have positive influences on LWP in smallholder farming systems in developing countries. A collaborative or integrative management approach is recommended for long term crop, livestock, land and water management, which are crucial in improving LWP in smallholder mixed crop-livestock farming systems.

Key Words

Smallholder farmers, LWP, feed management, forage quantity and quality, vulnerability, resilience

Mduduzi Khuzwayo	890308 5780 08 5	MSc	Assessing Physico-Chemical Properties of Soil Under Infield Rainwater Harvesting and its Effect on Crop Growth and Development	Section 5.3, 5.4	Writing up

Abstract

Low and erratic rainfall are major limiting factors to food production in South Africa, particularly for communal farmers who rely on rainfed agriculture. It is therefore important that rural farmers optimise the utilisation of their limited water resources. Rainwater harvesting and conservation (RWH&C) technologies offer alternatives to improve agricultural production. The aim of this study was to assess the effect of micro catchment rainwater harvesting (contour ridge and stone bunds) on selected soil physico-chemical properties and crop yields. The study was conducted in Muden, KwaZulu-Natal (KZN) and Ntshiqo, in Eastern Cape (EC) province. Key soil parameters were assessed over two growing seasons (2013/14 and 2014/15). The study was conducted in participation with five homestead farmers in Ntshiqo and three homestead farmers in Muden. Soil samples were collected at 0 - 100, 100 - 200 and 200 - 300 mm depths and subjected to chemical analysis (exchangeable bases, micro-nutrients, pH, electric conductivity and available phosphorus) and physical analysis (bulk density and aggregates stability at planting and harvesting). Gravimetric soil moisture content (GMC) was assessed at different stages of maize growth (planting, early vegetative growth, late vegetative growth, tasselling and harvesting). Plants were also analysed for above-ground biomass and grain yield.The RWH&C treatments had higher micro-nutrient concentrations, higher soil GMC and aggregate stability when compared with the controls. Additionally, bulk density was found to be lower in the RWH&C treatment. Soil pH, however was lower in the RWH&C treatment, with an associated decrease in exchangeable bases. In terms of yields, the severe drought in KZN resulted in the crop failure at the research sites during the period in question. The Eastern Cape had better rainfall which allowed for yield and biomass assessments. Compared with the control, the RWH&C treatment improved grain yield at three of the five sites and biomass yield at two of the five sites in the Eastern Sites. RWH&C improves some soil physico-chemical properties and overall has a positive effect on grain and biomass yields. The Eastern Cape sites performed better than the KZN sites due to more favourable climatic condition during period in question.

<table>
<tr><td>Nondumiso Sosibo</td><td>930831 0700 08 1</td><td>Honours</td><td>Assessing the Influence of Rain Water Harvesting Techniques on Soil Chemical And Physical Properties Compared to the Traditional Farmer's Practice</td><td>Section 5.3, 5.4</td><td>Degree awarded</td></tr>
<tr><td colspan="6">Abstract
Msinga area in KwaZulu-Natal is characterised by arid to semi-arid climate and erratic rainfall. Msinga community is dependent on subsistence farming for food consumption yet it is challenging because of water scarcity that is highly pronounced in this area. The rainwater harvesting has been implemented in this community to alleviate water shortages and perhaps terminate the food insecurity in this area. A study was conducted with the aim of assessing the impact of water harvesting techniques on soil physiochemical properties and to compare the performance of rainwater harvesting techniques in comparison with the traditional farmer practice. Bulk density, texture, pH, EC, moisture, available phosphorus, total nitrogen, total carbon, zinc, copper, cobalt, iron and manganese were analysed. The results show that rainwater harvesting is very beneficial in terms of soil moisture. It was found soil moisture can increase up to 28% with the supplement of rainwater harvesting. Up to 134.56 mg/kg of manganese can be found in the rainwater harvesting trials. It is advisable that the farmers adopt the rainwater harvesting to improve soil properties and crop yield.</td></tr>
<tr><td>Ntethelelo Dlamini</td><td>911014 5853 08 9</td><td>Honours</td><td>Effect of different rainwater-harvesting techniques on selected soil physical and hydraulic properties at Msinga and Ntshiqo</td><td>Section 5.3, 5.4</td><td>Degree awarded</td></tr>
<tr><td colspan="6">Abstract
Water insufficiency in arid and semi-arid regions due to little rainfall and uneven distribution during the course of the season makes rain fed agriculture in such areas a risky enterprise. Some parts of the world where water is the limited resource have started to grow interest in other techniques such as ridge-furrows, contour bunds to stretch the efficiency of that little water they have. In rural Msinga, KwaZulu-Natal Province, South Africa and in other places such as Ntshiqo, Eastern Cape, rainwater harvesting system has been used to supplement the conventional water supply systems for agricultural uses, The objectives of the study was to evaluate the variation on soil physical qualities (i) water content, (ii)bulk density, (iii)aggregate stability, (iv)hydraulic conductivity from the different water harvesting techniques and their effects on soils as they were used on subsistence farming of Msinga and Eastern Cape. The moisture regimes changes with depth. Bulk density was affected by clay percentage and other physical activities on study sites. Hydraulic conductivity declined with increasing clay percentage at depths. No significant changes in aggregate stability. More work need to be done to produce a trend over the growing season and the precise variation of physical and hydraulic properties in relation to water harvesting techniques.</td></tr>
</table>

APPENDIX IV: SURVEYS AND RELATED RESEARCH TOOLS

Interviews with farmers to understand cropping and livestock systems

1.1 What were the main cropping constraints before the introduction of RWH&C (separate by homesteads and fields)?
1.2 How were these constraints addressed by farmers in general?

1.3 Did RWH&C address some of these constraints (Look at changes over time – 2013 to 2016 trials) - What changed with regards to crop production. - ***Ranking exercise using set criteria***

1.4 Key lessons learnt throughout the experimentation process and ideas for taking lessons forward

Criteria	**Treatment (2013 -2016)**	**Control (2013 -2016)**
Yield		
Easer of weed control/management		
Labour requirements		
Maize stover for livestock grazing		
Moisture retention		
Other		
Rank		

1. Livestock
    a. What is working with the current rangeland management systems in communal areas?
    b. What are the key challenges with respect t to communal grazing as a shared common property?
    c. The introduction of rotational resting, what impact did it have on livestock production: What changed?
    d. What would be required to take this forward (technical/financial/ institutional and governance)?
    e. Do you know about the benefits of spring burning? Why it is not practiced?
2. Livestock/crop linkages
    a. How important are crop areas for livestock in winter?
    b. What did you think about the vetch and oats demonstrations?
    c. Have any of you applied this subsequently
3. Requirements for upscaling and outscaling
    a. What would be required to upscale (from homestead garden to fields)
    b. What would be required to outscale (from one village to more villages?)
    c. What can you do as a farmer?
    d. What would need to be done as a community?
    e. What support would be required? Extension, NGOs, etc.

Participatory Evaluation Process: RWH&C Project

Dates	Activity details and Participants	Time
26 July 2016 – Afternoon	Interview with key informants ▪ Nkosi Lutuka ▪ Mr Tshabu ▪ Mr Nongcawula – Dept of Agriculture	13: 00 to 16:30
27 July 2016 – Ntshiqo	Cropping Trial Farmers	9:00 to 12:00
27 July 2016 – Ntshiqo	Livestock Working Group and sheep farmers	13:00 to 16:00
28 July 2016	Interview with individual sheep farmers – data collection *(Lambing percentage Nov 2015 to June 2016)*	8:00 to 11:00
21 July 2016 – Fabeni	Cropping trial farmers livestock farmers participating in supplementary feeding experiment ▪ Meet with Ndunankulu Zakwe	10:00 to 13:00
22 July 2016 – Mxheleni	Mxheleni Women's group	10:00 to 13:00

Survey form to determine current levels of productivity of farmers

Name of farmer/ Igama likaMlimi:

Area/ Indawo:

	Maize yields/ Isivuno sombila				Amabhece - mangaki	Uchokwane-amabhakede amangaki (10kg)
Date/Usuku	Green mielies harvested/ Ovunwe ukuhlaza (mungaki)	Dry maize harvested/ Ovunwe usuwomisiwe				
		Own consumption/odliwe ekhaya-izinkobe (mungaki)	Animal consumption/Ophiwe imfuyo-izinkukhu noma izinkomo njll. (mungaki)	Dry maize kept for seed/ osetshenziselwe imbewu (mungaki)		

Livestock productivity surveys sheets

Goats					
04/04/2014	Farmer Name		Ward		
Monthly Costs					
Medicine (Describe)	Cost	Type of feed given	Cost	Other costs (describe)	Cost
Dectomax	120				

Deaths	
Explain the cause of death of your goat(s)	
Describe any symptoms you may have noticed	
What medication did you use?	
Illness	
Describe any symptoms you may have noticed	
Describe how you cured the goat(s) and how many times	

	Goat numbers today			Goats added from outside		Goats removed from the herd			
	How many goats do you have today	Does with one kid	Does with two kids	Goats purchased	Goats received (other - describe)	Goats sold (how much)	Goats slaughtered	Goats lost or stolen	Goats that died
Does									
Does without kids (Imbuzikazi)									
Bucks									
Castrated kids									
Weaned female kids									
Weaned male kids									
Female kids (not weaned)									
Male kids (not weaned)									
TOTAL									

Describe any other benefits from livestock products (e.g. milk, wool, manure, draft). Please quantify the benefit (e.g. hours of draft, litres of milk, kg wool, amount of manure used)
Additional comments or information

Cattle						
Date	Farmer Name			Ward		
Monthly Costs						
Medicine (Describe)	Cost	Type of feed given	Cost	Other costs (describe)	Cost	

Deaths	
Explain the cause of death of your cattle	
Describe any symptoms you may have noticed	
What medication did you use?	
Illness	
Describe any symptoms you may have noticed	
Describe how you cured the cattle and how many times	

	Cattle numbers today			Cattle added from outside		Cattle removed from the herd			
	How many cattle do you have today	Cow with calf		Cattle purchased	Cattle received (other - describe)	Cattle sold (how much)	Cattle slaughtered	Cattle lost or stolen	Cattle that died
Cows									
Heifers (Inkomazi)									
Bulls									
Oxen									
Weaned cows									
Weaned bulls									
Female calves (not weaned)									
Male calves (not weaned)									
TOTAL									

Describe any other benefits from livestock products (e.g. milk, wool, manure, draft). Please quantify the benefit (e.g. hours of draft, litres of milk, kg wool, amount of manure used)
Additional comments or information

Sheep									
Date	Farmer Name				Ward				
Monthly Costs									
Medicine (Describe)	Cost	Type of feed given			Cost	Other costs (describe)			Cost
Deaths									
Explain the cause of death of your sheep									
Describe any symptoms you may have noticed									
What medication did you use?									
Illness									
Describe any symptoms you may have noticed									
Describe how you cured the sheep and how many times									
	Sheep numbers today			Sheep added from outside		Sheep removed from the herd			
	How many sheep do you have today	Sheep with one lamb	Sheep with twins	Sheep purchased	Sheep received (other - describe)	Sheep sold (how much)	Sheep slaughtered	Sheep lost or stolen	Sheep that died
Ewes									
Heifers (Imbuzikazi)									
Rams									
Hummels									
Weaned female lambs									
Weaned male lambs									
Female lambs that have not been weaned									
Male lambs that have not been weaned									
TOTAL									
Describe any other benefits from livestock products (e.g. milk, wool, manure, draft). Please quantify the benefit (e.g. hours of draft, litres of milk, kg wool, amount of manure used)									
Additional comments or information									

All data collected through this research project is stored in electronic format and is accessible at:

Institute of Natural Resources

67 St Patricks Rd

Scottsville

3209

Email: info@inr.org.za

9781431208807