An analysis of the economic competitiveness of green maize production in smallholder irrigation schemes: A case of Makhathini Flats irrigation scheme in KwaZulu-Natal, South Africa

By

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Dedication

To my family, you are the best. I love you all!

Declaration

I, **Chirigo Kudakwashe Collen,** declare that;

1. The research reported in this thesis, except where otherwise indicated, is my original research;
2. This thesis has not been submitted for any degree or examination at any other university;
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As candidate's main supervisor, I, **M. Mudhara,** agree to the submission of this thesis;

Signed ____________________ Date______________________

As candidate's co-supervisor, I, **J. Derera,** agree to the submission of this thesis.

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Abstract

Recent assessments of smallholder irrigation schemes indicate that their success has been limited. Factors that contributed to their modest performance were poor infrastructure, limited knowledge of crop production among smallholders, lack of reliable markets and ineffective credit services. However, studies have not looked at the economic competitiveness of different crops grown under irrigation and efficiency in the allocation of farm resources. Different crops are grown in the irrigation schemes, but there is no economic criteria employed for analysing the economic competitiveness of the crops grown and on how choices are selected to maximise farmers' profits.

The aim of the study was to conduct an analysis of the household level characteristics on decisions to grow green maize and on the proportion of land allocated to it by smallholder farmers in Makhathini Flats irrigation scheme. A random sample of 150 farmers was drawn from a population of 314 irrigation farmers. The Heckman two-step regression model was used for assessing determinants of the decision to grow green maize. The results reveal that age, household size, plot size, extension and green maize gross margins significantly affect the decision to grow green maize, while gender, marital status, plot size, credit, gross margin of cabbages and green maize significantly affect the proportion of land allocated to green maize production. The study also sought to determine the economic competitiveness of green maize production as compared to alternative crops grown in the scheme using gross margin budget analysis and LP model. The gross margins analysis reveals that cabbage is the only crop with higher gross margins than green maize. The LP results also paint the same picture, indicating green maize competitiveness to other crops except cabbages. A factor contributing to the competitiveness of green maize is being an enterprise with low production costs compared to other enterprises. Farmers indicated that they lack capital to finance large pieces of land for crops with high production costs and the study concluded that availing credit to farmers could increase farm profits from enterprises with high production costs.

Farmers indicated that they also produce for subsistence. This means that certain crops are not grown based on their economic viability, but rather on their contribution to household food security. More often than not, these goals are conflicting. The study recommends formulating a multi-criteria decision-making model that aims at allocating farm resources efficiently by optimising a set of important socio-economic objectives.

List of acronyms

DAFF	Department of Agriculture, Forestry and Fisheries
DoA	Department of Agriculture
FAO	Food and Agriculture Organization of the United Nations
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute.
KZN	KwaZulu-Natal
LP	Linear Programming
ME	Marginal Effects
MVP	Marginal Value Product
NDA	National Department of Agriculture
OLS	Ordinary Least Squares
SA	South Africa
SAFEX	South African Futures Exchange
SIS	Smallholder Irrigation Schemes
STATSSA	Statistics South Africa
TLUs	Tropical Livestock Units
VIF	Variance Inflating Factors
WRC	Water Research Commission
UNDP	United Nations Development Programme

Table of Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

1.1: Background

Maize (*Zea mays* L.) is the most important summer grain crop in terms of both cultivated area and number of growers in smallholder irrigation schemes in South Africa (Fanadzo *et al.,* 2010). Maize is the most important field crop in South Africa and annually covers an estimated 30 percent of the total arable land (DoA, 2003; Gouse *et al.,* 2008). STATSSA (2010), reported that the largest area of farmland planted with field crops is maize, followed by wheat and, to a lesser extent, sugar cane and sunflower seed. Maize is one of the most important grains in South Africa in terms of number of farmers that engaged in its cultivation and in its economic value (Iken and Amusa, 2004). According to STATSSA (2010), the gross value of maize per annum is R13 522 million, followed by sugarcane and wheat with R4 825 million and R3 191 million respectively.

Maize is used in a variety of ways and it can be cooked, roasted, fried, ground, pounded or crushed to prepare various food items (Abdulrahaman and Kolawole, 2006). Green maize (fresh on the cob), consumed as parched, baked, roasted or boiled, plays an important role in filling the hunger gap after the dry season (Sobukola *et al.,* 2013). According to IITA (2009) maize contains 80 percent carbohydrate, 10 percent protein, 3.5 percent fibre and 2 percent mineral. Iron and Vitamin B are also present in maize. The crop has thus grown to be a local "cash crop" in most African countries where at least 30 percent of the cropland has been put to maize production under various cropping systems (Ogunsumi *et al.,* 2005).

Considering the importance of green maize, its production under smallholder irrigation has to be analysed economically so at to make maximum utilisation of the available farmer resources. Water for irrigation is increasingly becoming limited owing to increased demand from other uses such as domestic water, industries and the environment (Gomo *et al.,* 2013), so the best profitable crop has to be grown if farmers are to maximise their profits.

The importance of smallholder irrigation schemes arises primarily from their location in the former homelands, which continue to be poverty nodes (Vink and van Rooyen, 2009). In these areas, irrigated farming has the potential to contribute significantly to food security and income of participating farmers (Bembridge, 2000; Baiphethi and Jacobs, 2009). Furthermore, (Nhundu and Mushunje, 2010; Hussain *et al.,* Undated) posit that access to reliable irrigation can enable farmers to adopt new technologies and intensify cultivation, leading to increased productivity, overall higher production, and greater returns from farming. This, in turn, opens up new employment opportunities, both on-farm and off-farm, and can improve income, livelihoods, and the quality of life in rural areas (Nhundu and Mushunje, 2010).

For many decades, smallholder irrigation schemes have generated public interest, mainly because their establishment and revitalization were possible through the investment of public resources (Van Averbeke and Mohamed, 2007). More recent assessments of the sector concur that the success of smallholder irrigation has been limited (Bembridge, 2000; Crosby *et al.,* 2000). Gyasi *et al.* (2006) state that in many countries, institutional weaknesses and performance inefficiencies of public irrigation agencies have led to high costs of development and operation of irrigation schemes. Poor maintenance and lack of effective control over irrigation practices have resulted in the collapse of many irrigation systems (Nhundu and Mushunje, 2010). Rukuni *et al*. (2006) state that a number of problems have befallen irrigation schemes that are managed by central government departments, such as poor marketing arrangements, limited access to water, inability to meet operational costs due to poor fee structures and the lack of a sense of ownership, financial viability and poor governance. Some of these problems have necessitated government to transfer responsibility to farmers, who have continued to mismanage these systems, hence their dilapidation.

Another factor that constrained the economic impact of smallholder irrigation is the predominance of subsistence-oriented farming. Malatji (2006) reported that only 8 percent of farmers on smallholder irrigation schemes produce solely for commercial reasons, 77 percent of irrigation farmers engage themselves in farming for consumption and market purposes, and finally 15 percent for consumption only (i.e., they consume the produce and maybe give surpluses to relatives and neighbours). A small number of small-scale farmers participate in the markets (Makhura and Mokoena, 2003) and this raises a major concern. Bellemare and Barrett (2005) and Arcus (2004) argued that if many households do not participate actively in markets or do not respond to market signals, market-based development strategies may not facilitate wealth creation and poverty reduction.

Further to the above constraints, Adejobi *et al.* (2003) state that efficient allocation of farm resources by smallholder farmers through an optimal crop enterprise combination among their multiple goals of providing food for the family and accumulating monetary income has been evasive in sub-Saharan Africa. This is because smallholders also produce for own consumption (Adejobi *et al.,* 2003). Different crops are grown in smallholder irrigation schemes such as Makhathini flats irrigation scheme. There is no defined system or criteria on how to select a crop mix or choice. Cousins (2013) conducted a study at Tugela Ferry irrigation scheme, which is located in the Midlands region of KwaZulu-Natal (KZN) and noted that between 2009 and 2011, crops grown comprised green maize, tomatoes, sweet potatoes, cabbages, beans, onions, spinach and butternut squash. However, it is not clear, which amongst the crop(s) grown in smallholder irrigation schemes, are more profitable considering the input and output markets, plot size, household level characteristics and the crop production systems practiced.

The uneconomic crop choices that the smallholder farmers make could in fact result in them realizing low returns from their activities, and in the long run result in sub-optimal performance of the irrigation schemes. In much of the developing world, many smallholder farmers grow crops for local or personal consumption, to the detriment of the market-based options, which are profitable (Ashraf *et al.,* 2005). Support for food crops mainly from government, critics say, has compelled farmers to ignore other crops such as fruits, vegetables, and other grains, which are more profitable to the farmers (Scott, 2004). Lack of technologies and information about crop profitability usually makes farmers fail to make economic crop choices (Arriagada, 2005; Bareja, 2011). This could possibly lead to the inability of the smallholder farmers to invest in the schemes, or lack of interest in the management of the scheme activities. This therefore points to the need for appraisal of the crop mixes and choices to determine the economic competitiveness of different cropping enterprises under smallholder irrigation schemes.

Latruffe (2010) defines competitiveness as the ability to produce and sell products that meet demand requirements and at the same time, ensure profits over time that enables the firm to thrive. The same definition, adopted in this study assesses the competitiveness of different crops grown under irrigation by smallholder farmers.

1.2: Research problem

Generally, smallholder irrigation schemes in South Africa have performed poorly and have not delivered on their development objectives of increasing crop production and improving rural livelihoods. Limited knowledge about the economics of irrigated crop production among farmers is one of the constraints to improved crop productivity (Fanadzo *et al.,* 2010).

Maize (*Zea mays* L.) is the most important crop in terms of both cultivated area and proportion of growers in smallholder irrigation schemes in South Africa (Fanadzo *et al.,* 2010). It is cultivated both as grain maize and green maize (Fanadzo *et al.,* 2010). Previous research on maize production in smallholder irrigation schemes have focused on maize grain yields, efficiency of the irrigation in terms of water use and other agronomic aspects. However, attention to the economic competitiveness of maize production in smallholder irrigation schemes is lacking.

Dixon *et al.* (2005) suggest that most smallholders have diverse sources of livelihood including significant off-farm income. Smallholder irrigation farmers differ in their resource endowments, resource distribution between food and cash crops, livestock and off-farm activities, their use of external inputs and hired labour, the proportion of food crops sold and household expenditure patterns (Machingura, 2007). The differences highlighted above are typical of smallholder irrigation farmers in Makhathini Flats irrigation scheme, where different crops are grown without any well-defined criteria for selecting crop-mix to maximize returns.

McCown *et al.* (2012) noted that most farmers rely heavily on an intuitive approach to farm planning and decision-making. However, intuition is not enough in allocating scarce farm resources among production alternatives to maximize profits. Smallholder irrigation farmers often devote high proportions of area to staple food crops, which are low yielding and consumed locally, than they do to cash crops with high market returns or sold in urban markets or exported (UNDP, 2012). However, smallholder farmers do not produce purely for marketing, but also for household consumption. Food-crop production remains a major component of the farm-family economy (Adejobi *et al.,* 2003). Economic returns on produced crops apply where farmers only produce for marketing.

Considering that agriculture is a major source of income in Makhathini Flats irrigation scheme (Yousouf *et al.,* 2001; Morse and Bannett, 2008), and other smallholder irrigation schemes, there is a need to determine the economic competitiveness of green maize production under irrigation, which can help farmers to make better informed decisions in their choices. Since smallholder irrigation farmers are faced with the challenge of rationing their scarce resources among several intended activities (Tanko *et al.,* 2011). Therefore, this creates an allocation problem, which this study addresses by assessing the economic competitiveness of green maize production as compared to other alternative crops grown in Makhathini Flats irrigation scheme. The prototype enterprise combination developed in this study provides an answer on the optimal resource allocation that enhances farm business profitability.

1.3: Study objective

Generally, the research seeks to determine the competitiveness of green maize production in Makhathini Flats irrigation scheme in comparison to alternative crops and also to identify factors that determine its viability.

1.3.1: Specific objectives

- To understand the maize production systems practiced at Makhathini Flats irrigation scheme.
- To determine the effects of household level characteristics on the decision to produce maize and the area under green maize decisions in Makhathini Flats irrigation scheme.
- To determine the economic performance of green maize production as compared to alternative crops grown in Makhathini Flats irrigation scheme.

1.4: Research questions

- What are the production systems in maize production in Makhathini Flats irrigation scheme?
- How do household level characteristics effect the decision to produce and the area under green maize in Makhathini Flats irrigation scheme?
- What is the economic performance of green maize as compared to alternative crops grown in Makhathini Flats irrigation scheme?
- What are the policy measures that could enhance the production of green maize?

1.5: Expected research outcomes

The study expects that green maize production is a profitable enterprise compared to the alternative crops in the study area. This study results will help farmers in making effective farm decisions, efficient allocation of farm resources and choosing farm enterprise combinations, which will maximise returns.

1.6: Organisation of the study

The study has five chapters. The first chapter, being chapter one, comprises of the introduction, background, research problem, research objectives, research hypothesis and expected research outcomes and organisation of the thesis.

Chapter two is the literature review, which reviews the work done by earlier studies on the economic competitiveness of crops grown in smallholder irrigation farming. This chapter gives a theoretical base for studying the economic competitiveness of green maize production under irrigation by smallholder farmers comparing it to alternative crops grown. The chapter also captures empirical studies done in South Africa and outside on the economic competitiveness of green maize production under smallholder irrigation. It also considers maize production systems in smallholders' irrigation schemes, effects of household level characteristics on green maize production, economic performance of green maize production under irrigation as compared to alternative crops. The third chapter introduces the study area, the analytical framework and the empirical models used. The fourth chapter presents the results. Descriptive, econometric and statistical methods used for presenting the gathered and analysed data on the effects of household level characteristics on the decision to grow green maize and economic competitiveness of green maize production under smallholder irrigation scheme in Makhathini Flats. Chapter five concludes the findings from the study. The policy recommendations are also made in this final chapter.

CHAPTER 2: LITERATURE REVIEW

2.1: Introduction to literature review

This literature review provides a detailed background to the issues studied in this thesis. One of the major aims of this study was to determine the economic competitiveness of green maize production compared to alternative crops under smallholder irrigation schemes. This chapter presents a detailed discussion on economic competitiveness and of alternative crops. The study also investigated effects of household level characteristics on green maize production. It was also necessary to explore literature on household-level characteristics and how they relate to decision-making on the proportion of total farm area allocated to green maize production. Discussions on crop production systems, household level characteristics and economic performance of green maize production will reflect this bias in this review.

2.2: Theoretical understanding of maize production in South Africa

In order to be able to analyse the competitiveness of green maize production under smallholder irrigation schemes, there is need to understand the theoretical framework from which smallholder green maize farmers operate. The section below will briefly discuss the maize marketing system used in South Africa, *ceteris paribus*, which has also influenced green maize production as a commercial crop under smallholder irrigation schemes.

The South African maize industry is historically an industry characterized by many controversial political decisions and debates. In early years, commercial maize farmers enjoyed the protection of favourable government policies and farmers were guaranteed profitable producer prices (DoA, 2003). However, in 1996 the maize market was liberalised and the maize marketing board was abolished (Chabane, 2004). There was a change in agricultural policies; the agricultural sector was deregulated in 1996 through the promulgation of the Marketing Act (Bayley, 2000; Sandrey and Vink, 2007).

Since 1997, product prices have been determined under a free market condition and are formally traded on South African Futures Exchange (SAFEX) (Botha, 2005; Boshoff, 2008; Traub, 2008). This necessitated many smallholder commercial farmers to change their crop choices and acreages for maize production as a strategy to make a profit from farming. Some farmers did not change the crop per se, especially the smallholder farmers, they started selling it green to reduce their stocks and increase profit margins. Those with irrigation started growing it outside the summer season and enjoyed better returns as they sell it green, as the case with the smallholder farmers Makhathini flats irrigation scheme.

From this background, a conceptual understanding of the economics and political environment in which South African maize farmers operate in is important in order to understand the factors determining farmer crop mix and choices, price formulations, risks and profitability and how these political and economic environment influences agriculture.

2.3: Competitiveness of South African Agriculture

The competitiveness of agriculture in developing countries and the viability of smallholder farming is restricted by access to technological innovations, economies of scale in provisioning more demanding supply chains, and a declining role and capacity of the state in servicing the small farm sector (Colleta, 2008). STATSSA (2008) indicated that removal of state support to farmers combined with low import tariffs left many South African farmers unable to compete in certain areas, such as wheat and milk, against farmers from developed countries who receive generous state subsidies. While the contribution of subsistence and smallholder farmers to agriculture is unclear, there is some evidence that ineffective farmer support programmes have prevented land reform beneficiaries from contributing to total output, and have resulted in a decline in agricultural production in the communal farming areas, leaving these farmers more vulnerable to global market changes than the commercial farmer (DAFF, 2011). Improving the design, planning and execution of Farmer Support Programmes thus becomes critical for increased production in the smallholder sector and for greater integration with the commercial farming sector (DAFF, 2011).

However, despite these challenges, performance data, indicate that the commercial sector has done relatively well since the early 1990s, with the real gross value of production of the commercial sector up from R35 billion in 1994/95 to close to R50 billion in 2007 (in rand values from the year 2000), and real net farm income has remained at around R10 billion, also in rand values from 2000 (DAFF, 2011). On the other hand, government-led initiatives to increase irrigated farmland have enabled other farmers to successfully grow export crops such as deciduous fruit, grapes and citrus (SA Yearbook 2008/9). The volume of agricultural exports increased dramatically, and the value of exports increased from 5% of agricultural production in 1988 to 51% in 2008 (SA Yearbook 2008/9). The net result has been a decrease in the area under production for staple low-value crops such as wheat and maize, and a dramatic increase in the export of high-value crops. Smallholder South African farmers cannot compete successfully with subsidised produce imported from overseas that is dumped in South Africa at below production cost (DAFF, 2009b). Farmers are requesting subsidies and asking for increased import tariffs, which will increase the cost of staples such as bread (Vink and Kirsten, 2002).

2.4: Status of smallholder irrigation farming in South Africa

In South Africa the term smallholder or small-scale irrigation is mainly used when referring to irrigated agriculture practised by black people (Van Averbeke and Mohamed, 2007). Dixon *et al.* (2005) explain that the term smallholder only refers to their limited resource endowment relative to other farmers in the sector.

South Africa has an estimated 1.3 million hectares of land under irrigation for both commercial and subsistence agriculture (Perret, 2002a). Smallholder irrigation schemes account for about four percent of the irrigated area in South Africa (Bembridge, 2000; Backeberg, 2006a). These schemes consume about 60 percent of the currently available water resources of the country (NWRS, 2002), and contribute about almost 30 percent of the total agricultural production (Backeberg and Groenewald, 1995; Yokwe, 2009; Fanadzo *et al.,* 2010).

Smallholder irrigators have been categorised into four groups, namely farmers on irrigation schemes, independent irrigation farmers, community gardeners and home gardeners (De Lange, 1994; Crosby *et al.,* 2000; Du Plessis *et al.,* 2002). Backeberg (2006a) estimated the number of South African smallholder irrigators to range between 200 000 and 250 000, but most of these were farming very small plots, primarily to provide food for home consumption.

According to Van Averbeke and Mohamed (2007), South African smallholder irrigation schemes are multi-farmer irrigation projects larger than five hectares in size that were either established in the former homelands or in resource-poor areas by black people or agencies assisting their development. Using this definition, Arcus (2004) estimated that the land on smallholder irrigation schemes was held by about 31 000 plot holders, representing about 15 percent of the total smallholder population.

The importance of smallholder irrigation schemes in South Africa arises primarily from the number of participants involved (Bembridge, 2000). By comparison, the 1.2 million hectares of irrigated land in South Africa, which is referred to as large-scale commercial, is held by about 28 350 land holders (Backeberg, 2006a, 2006b). Estimates of the combined command area covered by South African smallholder irrigation schemes range between 46 000 - 49 500 hectares (Bembridge, 2000; Backeberg, 2003; Arcus, 2004; Denison, 2006). This represents about 47 percent of the total smallholder irrigation area and 3.6 percent of the 1.3 million hectares under irrigation at the national level (Backeberg, 2006a).

However, smallholder irrigation schemes (SIS) in South Africa have performed poorly and have not delivered on their development objectives of increasing crop production and improving rural livelihoods (Fanadzo *et al.,* 2010). The poor performance of many SIS in terms of productivity and economic impact has been largely attributed to socio-economic, political, climatic, edaphic and design factors coupled with limited knowledge of new technologies such as hybrid seed (Bembridge, 2000; Assefa and Van den Berg, 2010) as well as lack of skills in crop production among farmers (Machethe *et al.,* 2004). Hart, (2011) added that the poor performance of SIS in South Africa is due to the application of new technologies within unsuitable (and often unstable) contexts resulting in these improved technologies not being adopted or not being functional.

2.5: Maize production systems under smallholder irrigation schemes

The National Department of Agriculture (NDA, 2005) suggests that the major characteristics of production systems of smallholder irrigation farmers are of simple, out-dated technologies, low returns, high seasonal labour fluctuations and women playing a vital role in production. The maize production systems in sub-Saharan Africa smallholder farmers often lack inputs such as fertilizer, improved seed, irrigation, and labor (IITA, 2009; Smale *et al.,* 2011). In the traditional maize growing areas, most smallholder irrigation farmers still grow local varieties during the rainy season and seed replacement is very low (Joshi *et al.,* 2005; Nagarajand and Smale, 2005).

Maize (*Zea mays* L.) is produced throughout the country under diverse environments (Du Plessis *et al.,* 2002) and is a crop for all seasons (Rodomiro, 2007). In summer maize is grown almost exclusively under rain-fed conditions (Joshi, *et al.,* 2007), though supplementary irrigation maybe applied in some cases to support the early growth of the crop during dry spells and to obtain high yields **(**Du Plessis *et al.,* 2002; Chikobvu *et al.,* 2010; Smale *et al.,* 2011). Winter maize is gaining importance because it is grown under irrigation and complemented by good management practices. It gives higher yields and more income than dry land maize (Joshi *et al.,* 2005).

Maize cropping systems vary among farms depending on the available resources and constraints, geography and climate of the farm (Altieri and Koohafkan, 2008) and considering other crops grown in the schemes, since there is a mixture of field and vegetable crops (Lahiff 2000; Denison and Manona 2007). The vegetable crops include cabbage, beetroot, onion, tomatoes, pumpkins and butternuts (Fanadzo *et al.,* 2010) and some rotations are practiced with maize. Other crops considered in the determination of maize production systems include cotton, groundnuts, sunflowers, sorghum, soya bean and cassava (Van Averbeke and Khosa, 2011).

2.6: Overview of green maize production in smallholder irrigation schemes

Green maize is grown in all continents except the Antarctic (Rodomiro, 2007; Rüdelsheim and Perseus Bvba, 2011). In Africa, green maize is produced in all seasons, and in winter under irrigation (Smale *et al.,* 2011). It is eaten in more than half the world's maize producing countries (IRRI, 2009). Initial estimates of the global value of sweet corn, baby corn and green maize suggest that green maize is one of the five most profitable vegetables in the world (Rodomiro, 2007). He added that the "big five" producers of green maize are China, the USA, Mexico, Peru, and Thailand. The global retail value of green maize is about US$13-32 billion (IRRI, 2009). For comparison, the global retail value of tomatoes is US$56 billion and around US$18 billion worth of watermelon, onions and brassicas (IRRI, 2009).

In Africa, farmers might choose to harvest green maize at the end of the dry season when food is really scarce, or sell it (Rodomiro, 2007). While maize produced for grain (or "dry" maize) is vital to food security in Africa, however a number of farmers harvest the crop early, or green (Rodomiro, 2007). Immature cobs are harvested soft, naturally humid grain eaten directly on the cob after boiling or roasted (De Long, 2005). From the grey literature, it shows that some farmers do not want to incur harvesting, drying and storage costs. The farmer observed that there are a lot of expenses involved in harvesting, drying and storage of maize (Van Averbeke 2008).

2.6.1: Green maize production under smallholder irrigation scheme: A case study of Dzindi irrigation scheme in Limpopo Province, South Africa

Maize covered about 95 percent of the cropped area, which amounted to 60 percent of the total irrigated surface (Van Averbeke, 2008). Morden technology in green maize production at Dzindi included use of hybrid seed, mechanical land preparation and application of chemical fertilisers and registered pesticides whilst traditional technology included the use of animal manures (limited), short-furrow irrigation, and control of weeds by hand-hoeing, open-pollinated varieties (Van Averbeke, 2008).

For September plantings, the optimum planting density for green maize production using cultivar SC 701 is about 4.0 plants m^{-2}, but planting density has to be reduced to about 3.0 plants m^{-2} when using the PAN 93 cultivar (Van Averbeke, 2008). He added that varieties ETZ 200 and SC 701 were superior in terms of cob length and other attributes.

2.7: Constraints facing green maize production under smallholder irrigation schemes

There are many investment opportunities in the agricultural industry, among them is green maize farming (Van Averbeke 2008; Mogeni, 2012). However, research on green maize production not reported in South Africa, which negatively affects both variety development and management (Qwabe *et al.,* 2013). Common constraints facing smallholder farmers in green maize production in less developed areas maybe classified into two groups, namely internal and external constraints, which might act as disincentives to increased production (Baloyi, 2010).

According to Stokes and Wilson (2006) internal factors are personal attributes, skills and competencies of the individual, which are crucial to how well a business faces up to the inevitable crises that arise. Important to note about these constraints is the fact that they are controllable by the owner/manager (Hove and Tarisai, 2013). These include liquidity problems, shortage of labour, and lack of skills, knowledge and education and a range of cultural factors that in some instances prevent effective management of resources (Stokes and Wilson, 2006). The removal of these constraints will assist the farmer to allocate resources in an economically optimal manner.

External constraints emanate from the broader agricultural environment and are largely beyond the control of the individual farmer (Baloyi, 2010). These include natural risks typical to agricultural activity, limited availability of inputs, credit, mechanisation, and marketing services, poor institutional and infrastructural support; inappropriate policies and legislation; restrictive administrative and social structures; and problems associated with land tenure and the acquisition of agricultural resources (Baloyi, 2010; Hove and Tarisai, 2013).

2.8: Household level characteristics affecting smallholder green maize production

Green maize production has been scarcely researched, however in general grey literature points out smallholder productivity in Africa is very low and highly variable (Duvel *et al.,* 2003). Technical efficiency is one of the most challenging factors affecting productivity of smallholder farmers in Africa (Elibariki *et al.,* 2008). Elibariki *et al.* (2008) defined technical efficiency is a component of economic efficiency which reflects the ability of a farmer to maximize output from a given level of inputs (i.e. output orientation). Elibariki *et al.* (2008) in his study measured technical efficiency of smallholder maize farmers and found it ranging from 0.011 to 0.910 with a mean of 0.606. He concluded that low levels of education, lack of extension services, limited capital, land fragmentation and unavailability and high input prices are found to have a negative effect on smallholder farm production.

2.8.1: Gender of household head

Women face greater barriers in farming than men (Curtis and Adama, 2013). They have significantly less access to land, extension and credit services and, often, markets (Curtis and Adama, 2013). Bamire *et al.* (2010) indicated that only male can leave their land to be fallow, as females do not have access to land that would allow them to leave some portion to fallow. This means that land access to women is limited, therefore limiting their capacity to engage in some cash crops, thus prefer to grow subsistence crops for household consumption.

Looking at labour, in many places in Africa, traditionally there has been a strict division of labour by gender in agriculture (Babatunde *et al.,* 2008). While African women play a huge role in agricultural production, gender division of labour links women to the production of food crops and men to cash crops (Peterman *et al.,* 2010). This division of labour is based on crop or task, and both types of division of labour by gender may occur simultaneously. These divisions are not static and may change in response to new economic opportunities (Pender and Gebremedhin, 2006). The standard explanation for this division of crops by gender is that women are responsible for feeding the family and thus prefer to grow subsistence crops for the household, whereas men are responsible for providing cash income and thus raise cash and export crops (World Bank, 2009).

Horrell and Krishnan (2007) included the number of working-age adults in the household as an indicator of labour availability found that differences exist between male household heads and de facto female household heads; male-headed households are larger, on average, by one person (4.14 versus 3.12 people). According to Okello (2012), he noted that low managerial capacity of women makes it difficult to grow both commercial crops and maize for family consumption. Taking into account all these factors, the situation with maize is particularly complicated considering that maize may be grown as both as cash and subsistence crop.

2.8.2: Farmers' age and maize farming experience

Age can affect the probability of a farmer being successful in farming (Dlova *et al.,* 2004). The higher the age of the household head, the more stable the economy of the farm household, because older people have relatively richer experiences of the social and physical environments surrounding farming (Hofferth, 2003). The older farmers are more experienced and would be more technically efficient than the youth (Nsikak-Abasi and Sunday, 2013). However Hofferth, (2003) noted that older farmers are believed to be more conservative than young farmers. Kuwornu *et al.* (2012) added that older are more likely to be credit constrained; this might be because young farmers are still agile and more receptive to new technologies. It might be expected that the farmer's age would therefore constrain the adoption of green maize production as a commercial crop.

2.8.3: Educational level of household head

A sound educational background can reinforce natural talent; it can provide a theoretical foundation for informed decisions (Machingura, 2007). The behaviour and decisions of the farmer depend partly on his level of formal education (Najafi 2003; Muneer, 2008). Dlova *et al.* (2004) found that the higher the level of education, the more successful the farmer was. When farming is the main source of income, higher education should enable the farmer to appreciate the advantages of new better paying crop enterprises (Najafi 2003), thus increasing farmers' education would certainly contribute to higher rates of adoption of new practices and engage in new more paying crop enterprises.

2.8.4: Labour availability

In farming communities, labour and power shortages at the household level have an immediate and dramatic impact on agricultural production (Bishop-Sambrook, 2003). The importance of family labour in farm work and the lack of mechanization in agricultural production imply that the availability of family labour is a prerequisite for a household to increase farm size (Takane, 2008). Smallholder farmers typically use family labour, with each member of the household old enough to participate in farming operations contributing (Mudhara *et al.,* 2002). The shortage of labour will affect the planting and harvesting activities of maize (Nonthakot and Villano, 2008). Due to the reduced availability of labour, households often change their cropping pattern to less labour intensive crops (Bishop-Sambrook, 2003).

2.8.5: Farm asset ownership

Producing for the market requires production resources, which include land, labour and farming capital (Baloyi, 2010). Availability of implements is critical to the farmer as they determine timing and the rate of land preparation (Chiremba and Masters, 2004). This can also affects the profitability of the smallholder farmer operations as it affects the total land to be cultivated and timing of farm operations (Anneke and Todd, 2011).

2.8.6: Size of landholding

Agricultural land is a crucial piece of all land use types (Audsley *et al*., 2006; Stehfest *et al*., 2007) and is arguably the most important asset in primarily agrarian rural societies especially in the rural areas of South Africa but is lacking in both ownership and size (Machingura, 2007). Most smallholder farmers have limited access to land (NDA, 2005). Limited access to large farmland definitely affects the scale of maize production (Oyetoro and Okunade, 2012). This has also implications on the adoption of agricultural technology by smallholder maize farmers (Chirwa, 2005).

The issue of the size as a possible constraint to maize crop production comes about because of the concern that new technological improvements and adoption of new crops being biased against small farmers (Djauhari, *et al.,* Undated). Jayne *et al.* (2010) noted that farmers with larger holdings of land are more motivated to grow more of commercial crops. Since most smallholder farmers own a small piece of land, it limits their farming activities, which ultimately reduces their profit (Simalenga *et al.,* 2000).

2.8.7: Draught power

The use of tractor power in agriculture by smallholder farmers has remained unaffordable and uneconomical for many of them (Simalenga *et al.,* 2000). The main option for these farmers is the use of animal draught power, which is an environmentally friendly and appropriate for smallholder farmers (Simalenga *et al.,* 2000). Draught animals can perform several operations on the farm such as ploughing, harrowing, planting, weeding and transportation (Fall *et al.,* 2003). Animal traction power enables households to cultivate greater areas of land and to execute agricultural operations timely (Asres *et al.,* 2013).

2.9: Factors affecting green maize profitability in smallholder irrigation schemes in South Africa

Green maize profitability has been scarcely researched, however grey literature points out that green maize genetic resources need to be improved (Rodomiro, 2007) and lack of suitable green maize hybrids appears to be the major hindrance (Qwabe *et al.,* 2013).

In general maize production studies have shown that input and output price, maize yields, market access and irrigation infrastructure significantly influences the profitability of maize production (Safa, 2005; Tchale and Sauer, 2007 and Fasoranti; 2008). Basnayake and Gunaratne, (2002); Ahmad *et al.*, (2005) and Kibaara (2005) added that farmers' access to certified seed, fertilizer use and access to credit are influencing factors to maize profitability. These factors are briefly discussed below.

2.9.1: Input price

Due to the high cost of production inputs and limited access to credit by smallholder farmers, very few of them have access to modern production inputs (Baloyi, 2010). Grey literature on green maize production under irrigation has noted that farmers have to consider the costs of maize seed, fertilizer and agricultural chemicals delivered at the farm gate. Price shifts for inputs can change production costs in both the short and long run (Duffy, 2013) and this can affect the profitability of green maize production.

2.9.2: Output price

There is no clear literature that has mentioned about the output price of green maize under smallholder irrigation schemes; the general rule of thumb is that the farmers' pricing system should factor in the production costs and a profit margin. However, Qwabe *et al.* (2013) noted that there is a great potential for green maize production in their study area of KZN. More income can be generated if desired traits for the consumers can be incorporated in hybrids to enable farmers to obtain a premium on green maize sales (Qwabe *et al.,* 2013).

However, Okello (2012) noted that output market failure results in poor output prices for smallholders. Since smallholders are resource poor, they find it difficult to compete in lucrative markets due to high transaction cost and they are compelled to market their produce to local communities in their areas, usually at lower prices (Baloyi, 2010). According to Montshwe (2006), smallholders have difficulties in accessing market information, exposing them to a marketing disadvantage.

2.9.3: Green maize yields

According to Kurukulasuriya and Mendelsohn (2007), crop yield is a very important factor to determining the profitability of maize production farmers. However, the current hybrids, bred for grain production, lack some key green maize traits (Qwabe *et al.,* 2013). She added that there are no suitable green maize hybrids, which are adapted to extremely hot conditions in summer, while only two hybrids SR 52 and SC 701 grow in winter. There are limited hybrid options for green maize production due to lack of general adaptation and value for use (Qwabe *et al.,* 2013). This is compromising the green maize yields, which in turn affects its profitability.

2.9.4: Green maize market access

Most smallholder farmers are located in the rural areas, particularly in the former homelands where both physical and institutional infrastructure limits their expansion and participating in lucrative markets (Baloyi, 2010). Rural service centres, nearby towns and cities are often important sources of inputs for farmers and provide a market for farm produce (Chaminuka *et al.,* 2008). In support, Okello (2012) mentioned that in smallholder agriculture, village markets are obviously the primary outlet, followed by middlemen facilities and co-operatives and at these three important outlets, the average price received is the determining factor in the farmer's choice of market.

Smallholders sell at their farms to passing private sector traders, often at much lower prices (Fairtrade Foundation, 2013). They lose large volumes of their farm produce because output markets usually fail for them because they are widely scattered making produce assembly costly, poorly organized and tend to trade in small volumes as there are thin markets, which only handle small volumes (Okello, 2012). Lack of skills needed to enter lucrative markets - with complex grades and standards (Okello, 2012) affects the profitability of smallholder farmers.

2.9.5: Tenancy of land

As an institution, land tenure plays a major role in the performance and development of the food sector by influencing the land ownership and use patterns as well as the productivity of the land (Dlamini and Masuku, 2011). The land ownership issues go well beyond small sizes of plots (Salami *et al.,* 2010).There are a number of means through which people in Africa have access to land, they may own it outright, they may have land allocated specifically to them through their lineage or village head, or they may acquire land through marriage (Doss, 1999; Akuffo, 2009). There is varying access to land, levels of quality, levels of individualization of rights and control by traditional authorities in Africa (West, 2000; Dlamini and Masuku, 2011).

Ayalew *et al.* (2005) argued that the perceived lack of transfer rights by farmers is the most important factor in explaining the relatively low investment in developing countries. Farmers' fear of expropriation over land on which they have invested deters investments (Goldstein and Udry, 2005). These insecure tenure systems such as communal land tenure system constrain the farmers from producing to their highest potential (Kariuki, 2003; Cousins, 2009).

2.9.6: Exposure to extension service

Extension has been defined as systems that facilitate the access of farmers, their organizations and other market actors to knowledge, information and technologies, facilitate their interaction with partners in research, education, agribusiness, and other relevant institutions and assist them to develop their own technical, organizational and management skills and practices (Sulaiman *et al.,* 2005; Birner and Anderson, 2007; Christoplos, 2010). Extension service is a good indicator of farmer's knowledge of agricultural information (Kaliba *et al.,* 2000; Birner *et al.*, 2006; Davis, 2008). The role of extension officers actually determines sustainability of development initiatives in the long run (Oettle and Koelle, 2003; Feder *et al*., 2010). The extension service should to encourage farmers to adopt new technologies in place of traditional methods (Anderson *et al.,* 2006). The more intensively a farmer is exposed to its activities, the more prepared and willing he should be to adopt new practices (Swanson, 2006).

2.9.7: Access to credit

Smallholder farmers suffer from a lack of credit access (Peacock *et al.,* 2004) yet access to credit can significantly increase the ability of poor household with no or little savings to acquire needed agricultural inputs to invest in future production, expand farming or diversify into producing new crops (Shah *et al.,* Undated). Smallholders cite the lack of capital and access to affordable credit as the main factor behind the low productivity in agriculture (Salami *et al.,* 2010). Yet the package of financial services available to smallholder farmers in developing countries is severely limited, especially for those living in remote areas with no access to basic market infrastructure (Kloeppinger-Todd *et al.,* 2010). While more recently micro-finance institutions have taken financial services to millions of previously un-bankable clients due to innovative instruments, they have so far largely failed to reach poorer rural areas and/or smallholder agricultural producers whose livelihoods involve highly seasonal investments, risks, and returns (Peacock *et al.,* 2004).

Banks and other finance institutions often perceive the cost of making small loans to smallholders as too high (Meridian Institute, 2013). There are also high administrative costs per unit of currency when lending to disperse farmers, alongside the small amounts of money borrowed that is, the costs outweigh the revenues (Fairtrade Foundation, 2013). Also because of the lack of collateral and/or credit history, most smallholder farmers are by-passed not only by commercial and national development banks, but also by formal micro-credit institutions (Curtis and Adama, 2013).

2.9.8: Irrigation infrastructure

The near or collapse of some irrigations schemes in South Africa can be attributed to a lack of funding and poor management and maintenance of infrastructure (Bembridge, 2000; Backeberg, 2006a). Evidence from Dzindi suggested that plot holder succession and livelihood diversifications are factors that contribute to the erosion of existing institutional arrangements pertaining to the routine maintenance of the irrigation infrastructure (Letsoalo and Van Averbeke, 2006c). Maintenance of infrastructure is an important domain in which institutional weaknesses impact negatively on productivity (Letsoalo and Van Averbeke, 2006b). Rehabilitating the irrigation infrastructure, providing effective extension services and facilitating access to information are public interventions that will undoubtedly be of benefit to smallholder irrigators (Van Averbeke and Mohamed, 2006).

2.9.9: Farmers' association

Farmers' associations are essential institutions for the empowerment, poverty alleviation and advancement of farmers and the rural poor (Penunia, 2011). Farmers' associations reduces transaction costs such as transport, search, negotiation and administration costs faced by farmers (Chikazunga, 2013) and enables knowledge sharing through networking, peer to peer training and good practice demonstrations which can yield widespread and significant benefits (Kumwenda *et al.,* 2013). Economically, farmers' associations can help farmers gain skills, access inputs, form enterprises, process and market their products more effectively to generate higher incomes (Robbins *et al.,* 2004; Penunia, 2011). By organizing, farmers can access information needed to produce, add value, market their produce and develop effective linkages with input agencies such as financial service providers, as well as output markets (Poole and Frece, 2010). Robbins *et al.* (2004) also noted that collective activity might also help farmers to obtain credit.

Figure 1.0 shows the combined constraints affecting green maize production. It also figures out the typical green maize distribution network, which is the marketing system of green maize in South Africa.

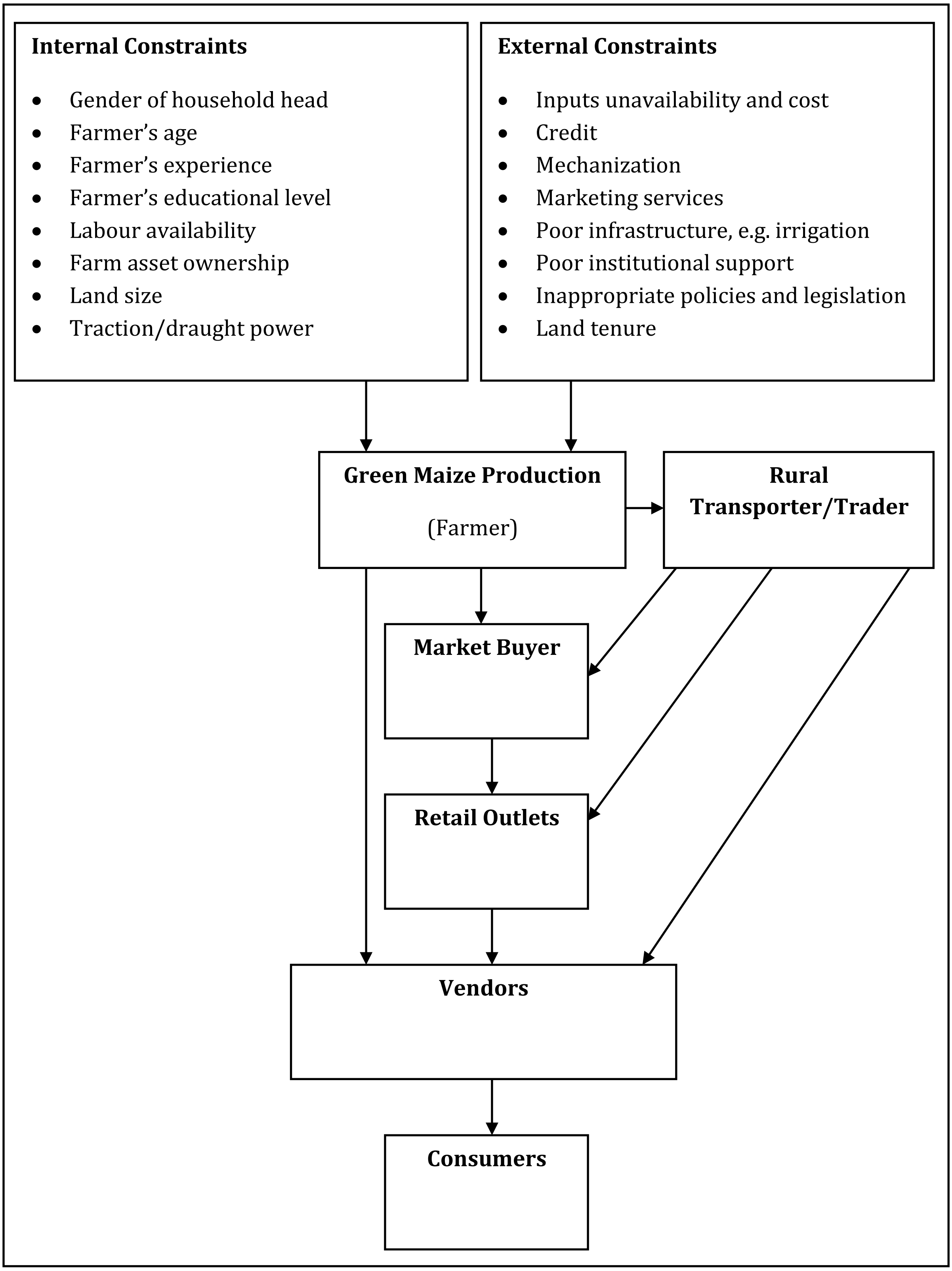

Figure 1.0: Conceptual framework showing constraints to green maize production and the green maize distribution network in South Africa.

Source: Adopted from De Long, 2005.

2.10: Green maize marketing in South Africa

Considering that green maize is a horticultural crop, its marketing is vital to the overall profitability of the green maize enterprise. The distribution network for green maize is complicated and often limits marketing opportunities for farmers, giving them little bargaining power (De Long, 2005). She added that informal channels such as roadside and farm gate markets have a significant share, while supermarkets and agro-processors are the least supplied. Hawkers, who cook the cobs and offer them for sale in the markets controls the trade in green maize (Van Averbeke, 2008). They select and harvest the cobs that met their quality requirements and the important criteria used for selection are size of the cobs, uniformity of grain filling, and the absence of damage by pests (Van Averbeke, 2008).

2.11: Returns to green maize production

Although the green maize market has been opportunistic, the green maize price point is two-to-three times higher than dry maize (De Long, 2005). Growing maize for the purpose of green maize sales enabled smallholders to obtain much higher gross margins than growing the crop for grain (Van Averbeke, 2008). Qwabe *et al.* (2013) on green maize production study noted that enterprise budget analysis revealed a total production cost of R11 263 ha^{-1}. The study showed revenue of R21 109 ha^{-1} and gross margin of R9 846 ha^{-1}. Green maize was produced in two seasons per year because the climate allows both winter and summer production and income was doubled to about R20 000ha^{-1}.

Van Averbeke (2008) also reported good returns from green maize. He indicated that nearly 85 percent of the maize produced during the 2001/2 season at Dzindi irrigation scheme in Limpopo province, South Africa, was for grain and the rest was harvested as green cobs but in monetary terms, the maize harvested as green cobs contributed more than 40 percent to the gross value of maize production. He added that on a mass basis, 43.7 percent of the total crop was for sale, with one-third being for green cobs and two thirds for grain. However, the maize sold as green cobs generated about two-thirds of the cash income generated from maize sales. This shows that green maize had better returns than grain maize sold for that particular season and scheme, which might be the case with other farmers with more or less the same resources and markets in South Africa.

2.12: Farm budgeting in smallholder irrigation schemes

Conventional techniques of analysis in farm management such as gross margin analysis, enterprise budgets and whole-farm budgets are widely used in developed countries to identify improvements and assess the value of change, however have not been widely adopted in developing countries (Rushton, 2009).

2.12.1: Gross margin budgeting in smallholder farming

A gross margin is the gross income from an enterprise less the variable costs incurred in achieving it (Davies and Scott, 2007). Gross margin is a key financial indicator used to assess the profitability of an enterprise, excluding fixed cost (Rushton, 2009). It is the financial difference received from sales of produce and the variable costs associated with producing that produce (Griffiths, 2013). The gross margin budgets are intended to provide a guide to the relative profitability of similar enterprises and an indication of management operations involved in different enterprises (Davies and Scott, 2007) and provides a simple method for comparing the performance of enterprises that have almost similar requirements of capital and labour (Griffiths, 2013).

Price sensitivity analysis can performed on gross margins, and a collection of gross margins can be used to select the best combination of enterprises (Rushton, 2009). Crop gross margins are measured on a per hectare basis and per mega litre of water in the case of irrigated crops (Davies and Scott, 2007). Simalenga *et al.* (2000) used gross margin budgeting on assessing profitability of smallholder farming in Eastern Cape Province, South Africa while Segun-Olasanmi and Bamire (2010) used the gross margin analysis on the costs and returns to maize and cowpea production for smallholder farmers in Oyo state, Nigeria. However, Rushton (2009) also indicated that gross margin budgeting maybe limited in smallholder farming because financial returns are not the only criteria for enterprise selection. Other constraints, such as the need to generate food gains, can play an important part in decision-making (Rushton, 2009).

2.12.2: Components of gross margin calculation for irrigated crops

Input level and cost

These can be classified as variable costs, and the costs vary in the short directly with the amount of output produced, declining to zero if output is zero (Rushton, 2009). It is widely known that smallholder farmers in developing countries use too few modern inputs and technologies, which often results in low yields and poor quality crops (Rabatsky, 2013). These mainly consist of seeds, fertilisers and agro chemicals (Duffy, 2013).

Labour is also a key asset for smallholder farming (Takane, 2008). The types of labour used in agricultural production can be classified into two categories, which are family labour and hired labour (Takane, 2008). The cost of labour is not included in the calculation of the farmers' income, when the household provides all the labour required (Osugiri *et al.,* 2012). However, when a household has insufficient family labour to complete the farm tasks, hired labour is used (Takane, 2008). Osugiri *et al.* (2012) noted that labour had the highest average factor cost in smallholder farming. Duffy, (2013) mentioned that in the short-run, cash income must be sufficient to pay cash costs, including seed, fertilizer, chemicals, insurance, cash rent and hired labour, machinery fuel and repairs and interest on operating costs. In the long run, income should be sufficient to pay all costs of production, for resources to be used in their most profitable alternative.

Yield

Yields are related to a particular production technology, as well as to a particular farming system and when calculating gross margins for farmers' practice, the yields used should represent realistic average yields under farmer conditions; these are usually well below the potential yields realised in research stations (Meindertsma, 2005). According to World Bank (2007), the average farmer in Sub-Saharan Africa produces only one ton of cereal per hectare. However, accurately estimating crop yields is never easy and is even more of a challenge in the context of African farming systems characterized by smallholder farms that produce a wide range of diverse crops (Todd and Anneke, 2011).

Output price or selling price

In farm budgeting, farm-gate or on-farm sales prices are used (Meindertsma, 2005). For smallholder farmers in South Africa, accessing produce markets remains a challenge, and as a result, markets do not serve the interests of smallholder (Van Schalkwyk *et al.,* 2012). Smallholder farmers sell most of their produce to rural traders immediately after the harvest due to limited infrastructure and access to market information resulting in lower output prices (Svensson and Drott, 2010). Furthermore, when farmers choose to sell their agricultural output, they typically do so by engaging in trade with local traders that buy their crops at the farm-gate, often with limited competition from other traders (Ferris, 2004). Mangisoni (2006) explained that smallholder usually accept low prices for their crops when the broker informs them that their produce is of poor quality. Smallholder farmers accept these low prices mainly because they are unable to negotiate from a well-informed position (Van Schalkwyk *et al.,* 2012).

2.13: Econometric model: The Heckman two-step regression model

The Linear Probability Model (LPM) is widely used in economics, even with the widespread implementation of alternatives like Probit and Logit (Humphreys, 2013). The major advantage of LPM is their easiness in correcting for heteroscedasticity (King and Roberts, 2013), which is useful for exposing the particular types of misspecification that may be present (Petersen 2009). If the outcome variable depends on a set of regressors or explanatory variables, x_i observable for each individual in the sample, then the conditional expectation of y_i is:

$$E\ [\ y_i | x_i\ ] = P(y_i = 1 | x_i) = F(x_i) \ \ldots\ldots \ [1]$$

To estimate the unknown parameters of equation [1], a number of approaches exist. The simplest case is when $F(\cdot)$ is assumed to be a simple linear function, $x_i\beta$. In this case, this is the "linear probability model" and OLS estimates the unknown parameters β. Humphreys, (2013) mentions that the linear probability model is convenient, and may not be a bad option if $F(\cdot)$ is approximately linear over the values in x_i, in terms of the probabilities of observing y_1 = 1.

However, when Y is binary, $\hat{Y}$ values estimates the probability that Y_i =1, yet the predicted probabilities generated by the linear probability model can lie outside the [0, 1] interval, leading to logical inconsistencies (Pohlman and Leitner, 2003; Humphreys, 2013). The normal distribution and homogeneous error variance assumptions of OLS will likely be violated with a binary dependent variable, especially when the probability of the dependent event varies widely (Maddala 1983, Pohlman and Leitner, 2003; Heckman and Vytlacil, 2005; Ying *et al.,* 2010). Beck (2011) argued that the OLS should not suitable for binary dependent variables because it has a very undesirable large sample property; it is inconsistent. In a recent paper, Horrace and Oaxaca (2006) indicated that the OLS is biased and inconsistent for binary dependent variables. That means you cannot trust the estimates to converge to the underlying population parameters, even in large samples (Angrist and Jorn-Steen, 2009; Humphreys, 2013). Also in cases where observations are selected in a process that is not independent of the outcome of interest and two mutually exclusive decisions are to be made, using OLS may lead to biased and inconsistent estimates (Bushway *et al.,* 2007). For these reasons, many researchers choose to use nonlinear approaches to estimate equation [1] (Humphreys, 2013). Heckman (1979; 1990) has proposed a simple practical solution for such situations, which treats the selection problem as an omitted variable problem. The model, known as the Heckman two-step or limited information maximum likelihood (LIML) and is expressed as follows:

Basic selection equation:

$z_i^* = w_i\gamma + \mu_i$ .... [2]

$$z_i^* = \begin{cases} 1 & if\ z_i^* > 0 \\ 0 & if\ z_i^* \le 0 \end{cases}$$

And a basic outcome equation:

$y_i = x_i\beta + \varepsilon_i$ .... [3]

$$y_i = \begin{cases} x_i\beta + \varepsilon_i & if\ z_i^* > 0 \\ - & if\ z_i^* \le 0 \end{cases}$$

The problem with the model arises when estimating β if μ_i and ε_i are correlated. The Tobit model becomes the special case where $y_i = z_i$. Typically, the Heckman two-step also makes the assumption about the distribution of, and relation between, the error term and the selection outcome equation:

μ_i ~ N (0, 1)

ε_i ~N $(0, \sigma^2)$

Corr (μ_i, ε_i) = p

Hence, Heckman (1979) characterized the sample selection problem as a special case of the omitted variable problem with λ being the omitted variable if OLS is used on the subsample for which $y_i^* > 0$. As long as μ_i has a normal distribution and ε_i is independent of λ, Heckman's two-step estimator is consistent.

2.14: Linear Programming (LP)

Optimization models have a long history of use in agricultural economic production analysis (Howitt, 2002). There is a progression from partial budget analysis in farm management used much of the early work in agricultural production to linear programming models (Howitt, 2002). Considering that farmers are usually faced with limited resource allocation problem among different farm enterprises (Alsheikh *et al.,* 2002), these farmers always seek an optimal mix of farming activities that maximizes their income (Majeke *et al.,* 2013). Farmers, often, follow their instinct and experience to handle this problem (Alsheikh *et al.,* 2002). Mohamad and Said (2011) also pointed out that, traditionally, farmers have relied on experience, intuition and comparisons with their neighbours to make their decisions. Instinct and experience do not guarantee optimal results; however, farm planners can offer effective techniques, such as, linear programming (LP), to address such a problem and produce optimal solutions (Alsheikh *et al.,* 2002). Linear programming can select optimal crop combinations subject to fixed farm constraints (Majeke *et al.,* 2013). Scarpari and Beaclair (2010) also argued that optimized agricultural planning is a fundamental activity in business profitability because it can increase the returns from an operation with low additional costs. Buysse *et al.* (2007) noted that the basic linear programming model is written as follows:

Max. $$Z = \sum_{j=1}^{n} c_j x_j \quad \text{[4]}$$

Subject to: $$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \quad \text{[5]}$$

$$x_j \geq 0 \text{ [Non-negativity assumption]}$$

Where: x_j is the level of farm activity *j*;

c_j is the forecasted gross margin of farm activity *j*;

a_{ij} is the quantity of resource *i* required to produce one unit of activity *j*;

b_i is the amount of the available resource *i*;

i is the index of resources and *j* is the index of activities.

The solution of this primal model gives information on which activities maximise the gross margin (Buysse *et al.,* 2007). Their applications are widespread due to their ability to reproduce detailed constrained output decisions and their minimal data requirements (Howitt, 2002). However, LP models are also limited largely to normative applications as attempts to calibrate them to actual behaviour by adding constraints or risk terms have not been very successful (Howitt, 2002). Buysse *et al.* (2007) added that the primal model provides, however, no information how to increase the gross margin by acquiring additional resources *i*. Therefore, we have to calculate the marginal value product of each resource *i*, in programming literature this is also called the shadow cost of the resources (Heckelei *et al.,* 2012).

2.15: Summary

Many crops are grown in the irrigation schemes without a defined criterion for crop selection. This might lead to low farm profits and poor performance of the irrigation scheme. Literature concludes that South Africa smallholder irrigation schemes have generally performed below expectations. The decision of the crop to grow is influenced by a number of factors, both internal and external to the farmer. Historically, gross margin analysis has been used to analyse and compare the performance of farm enterprises. However, gross margin analysis does not give optimal crop combinations to maximise farm profits given a number of crops to grow subject to resource constraints. This suggests the need to employ linear programming model, which is now widely used for farm enterprise selection with the objective of maximising returns. Most of the studies have concluded that linear programming is a better tool than gross margin analysis in farm management with the objective of maximising farm profits. This chapter has presented some evidence based on the available literature and the succeeding empirical chapters give more evidence on economic competitiveness of green maize.

CHAPTER 3: METHODOLOGY

3.1: Introduction

This chapter introduces the study area, sources and types of data used and the research methods employed in this study. A discussion of data collection procedures, methods and analytical models used in this study follows a brief description of the study area. Empirical methods that include the Heckman two-step regression model and the linear programming model are explained.

3.2: Study area

The Makhathini Flats cover the floodplains on either side of the Pongola river, stretching from just below the Jozini dam to the confluence of the Pongola and Usuthu rivers on the Mozambique border (Witt *et al.,* 2006) (Figure 2). More generally, the flats comprise of the low-lying areas east of the Ubombo mountains, covering some 13 000 ha (Witt *et al.,* 2006). The region falls within the Umkhanyakude district, and is characterised by chronic poverty, with 85.2 percent of households within the municipality earning less than R1 500 per month (Iyer-Rothaug *et al.,* 2002), making it one of the poorest districts in the province (Witt *et al.,* 2006). Socio-economic data in KZN place the district as one of the poorest in the province (Jozini Municipality, 2004). Hofs and Kirsten (2001) pointed out that the majority of farmers in the Makhathini area are smallholders; farming average land sizes around 2.5 to 5 ha. The Jozini dam and the subsequent establishment of the Makhathini irrigation scheme were to be the 'growth engine' for the sub-region (Jozini Municipality, 2004). According to the DoA (2003), the Agricultural Development Plan for KZN pointed out that Makhathini flats has climatic conditions which favour the cultivation of a number of agricultural crops under irrigation. This includes a mixture of field and vegetables crops.

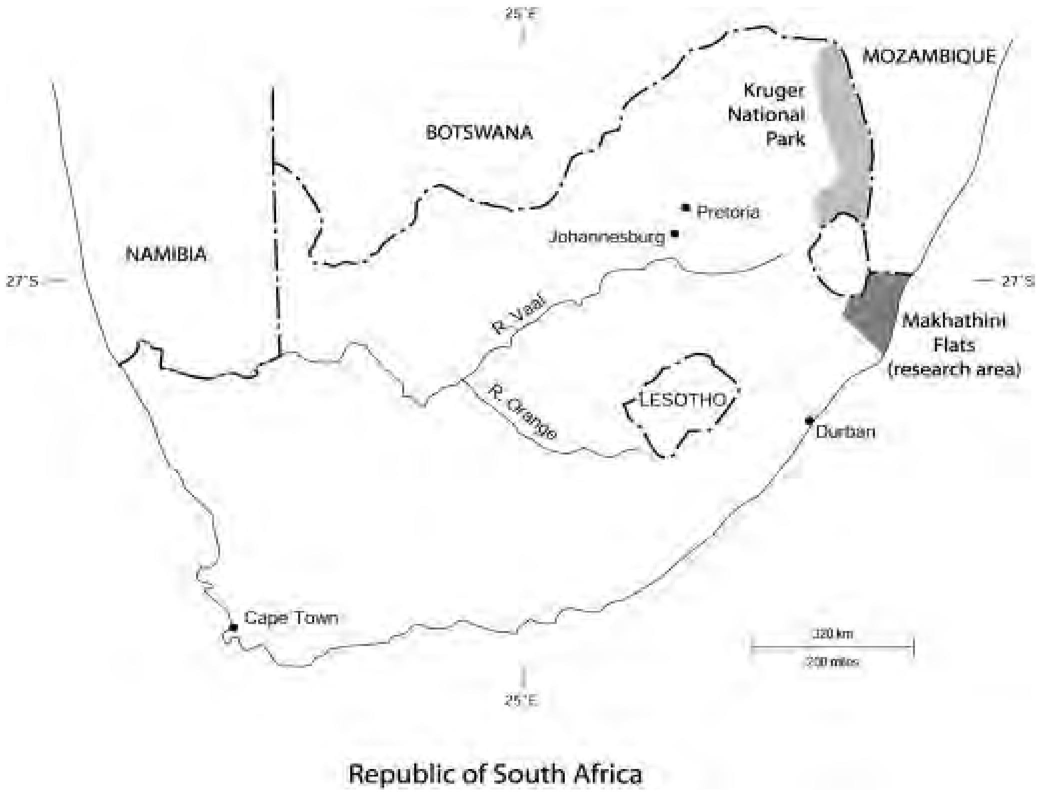

Figure 2.0: The Republic of South Africa with the research area (Makhathini Flats) highlighted. **Source:** DAFF, 2009.

The presence of many smallholder irrigation farmers who are into commercial green maize production throughout the year led to the choice of Makhathini flats irrigation scheme for this study. Qwabe *et al.* (2013) reported that in the study area and the crop was there is great potential for green maize production produced in two seasons per year; because the niche environment allows both winter and summer production. The area has a deep, fertile soil and has an enormous irrigation potential (Gouse, 2005). However, research on green maize production and its economic competitiveness under irrigation has been scarcely reported, which negatively impacts both farm enterprise selection and profitability, since its economic contribution has not been fully realised. This scheme currently has 3 500 ha under irrigation (Pringle, 2012). Some 1 200 ha is dedicated to sugar cane, with the balance planted maize and other vegetables (Pringle, 2012). Department of Agriculture, Environmental Affairs and Rural Development (DAEARD) estimate that about 1 500 ha of the developed irrigation land in Makhathini Flats irrigation scheme is underutilised (Pringle, 2012), which can support expansion of green maize production if the crop proves to be profitable.

Table 3.1: Description of variables used in the study

Variable		Variable Description	
Dependent Variables			
Growing green maize		The decision to grow green maize	
Proportion of land allocated to green maize		Proportion of land allocated to green maize was generated by dividing land under green maize over total land owned by farmer	
Independent variables			
Variables	**Measures**	H_0 **sign**	**Rationale**
Age	Years	+	Older farmers are likely to have more resource endowments and have higher chances of growing green maize.
Gender	1 = Male; 0 = Female	+/-	Female farmers tend to have labor and land constraints; however, they are the ones dominating smallholder irrigation schemes in Africa so the relationship can be two sided.
Marital Status	1 = Married; 0 = Single	+/-	Married farmers can have more labour to grow green maize; however the labour can be allocated to a more paying crop, therefore any relationship is possible.
Educational Level	Years of schooling	+	Educated farmers are more likely to grow green maize because of high green maize gross margins.
Household size	Adult equivalents	+	More labour, high probability of growing the crop and more land likely to be allocated to the crop.
Total Plot size	Hectares	+	Farmers with more land have more room for choice of additional crops.
Land ownership status	1 = Owning; 0 = leasing	+	Those who own the land can easily make a decision to grow cash crops.
Farm assets	Value of farm assets	+	Farmers with farm assets can grow the crop with less limitations of land preparation machinery.
Livestock size	Tropical livestock units	+	More livestock ownership can show farmers' economic status and these farmers can buy inputs.
Extension	1 = Yes; 0 = No	+/-	Extension advice can help farmers to decide which crops to grow, either negatively or positively.
Credit	1 = Yes; 0 = No	+	Credit access is likely to increase input access and the ability to pay for them.
Member of farmer association	1 = Yes; 0 = No	+/-	Like extension, advice from these farmer associations can influence growing green maize in any direction.
Participation in scheme management	1 = Yes; 0 = No	+/-	Participation in scheme management can also influence positively or negatively to green maize growing.
Gross margin green maize	Rands/ha	+	The more green maize gross margins, the increase in probability to grow and increase area under green maize.
Gross margin of competitive crops	Rands/ha	-	The increase in competitor crops' gross margins, the less the probability of growing and increasing area under green maize.

As shown in Appendices, people of different gender and age were adjusted using recommended scales to reflect household labour endowments. The scales that were used to calculate tropical livestock units (TLU) are presented in the Appendices.

Age: Age can affect the probability of a farmer being successful in farming. The higher the age of the household head, the more stable the economy of the farm household, because older people have relatively richer experiences of the social and physical environments surrounding farming.

Gender: There has been inequality on farm land ownership biased towards males (Hart and Aliber, 2011; ActionAid, 2011) yet women represent almost two-thirds of those engaged in some form of agriculture in South Africa (Hart and Aliber, 2009; Doss, 2011). The study looked at green maize production from a gender point of view since it is a crop grown both as a cash crop and for subsistence.

Education: The level of education of the heads of households is important since they are the decision makers on farming activities, especially crop choice and input selection. Education is a source of human capital and enhances the productive abilities of human beings as well as allowing them to adjust to new ways of production (Dae-Bong, 2009; Beach, 2009). Therefore educational status of head of household was expected to influence the decisions to grow and the proportion of land allocated to green maize production with educated farmers choosing and allocating more land to a crop with high, ceteris paribus.

Household size: Normally, the larger the family size, the more likely the farmer is to increase area under cultivation as family members are the immediate source of labour in smallholder farming (Takane, 2008).

Land ownership status: Land is an important resource playing a crucial role in smallholder farming. Land tenure is the relationship, whether legally or customarily defined, among people with respect to land (Hodgson, 2004). Land tenure status is an important factor in determining the productivity of farmers (Machethe et al., 2004; Tekana and Oladele, 2011). More so, farmers are more able to invest when secure freehold titles are established as the land acquires collateral value and access to credit becomes easier (Besley, 1995; Brasselle et al., 2002). This collateralisation effect is very important especially as formal lenders require collateral to lend to farmers. According to Fenske (2011), the most obvious means by which land rights increase access to capital is through the ability to use land as collateral.

Extension: Developing the skills base of farmers is the primary objective of extension. Extension officers bridge the gap between available technology and farmers' practices by providing technical advice, information and training (Treguetha *et al.*, 2010). However, due to the low number of extension officers, the accessibility of extension by the small-scale farmer is limited in South Africa (Greenberg, 2010). Hall and Aliber (2010) reported that only about 11% of the rural households contact an extension officer in a year. This implies that only a small fraction of the farmers get advice and/or training on modern farming methods. As a result, limited knowledge of crop production among farmers has been cited as one constraint to improved crop productivity in smallholder irrigation schemes (Machethe *et al*., 2004; Fanadzo *et al*., 2010; Fanadzo, 2012). According to Fanadzo *et al*. (2010), low yield levels caused by poor crop and water management practices by the farmers is arguably the main reason for the failure of many smallholder irrigation schemes in South Africa

Credit: This study considers farmers' access to credit as it affects land under cultivation. Lack of working capital and low liquidity limit the farmers' ability to purchase productivity-enhancing inputs like improved seeds, fertilisers and pesticides. According to Kiplimo (2013), credit is important in the transformation of traditional agriculture through the purchase of inputs, farm equipment and adoption of new technologies. Kibaara (2006) also indicated that agricultural credit is vital for smallholder to produce a marketable surplus and enhances economic growth by improving the profitability of farming enterprises.

Livestock: Livestock play a vital role in smallholder farming as they provide key inputs to crop agriculture and are used as a source of cash, which can be used to buy production inputs. Larger animals such as cattle are a capital reserve, built up in good times to be used when the farmer is facing large expenses such as the cost of wedding. Small stock like goats, with their high rates of reproduction and growth, can provide a regular source of income from sales, which can be used to buy less expensive crop production inputs. Different livestock ownership numbers were converted to the standard tropical livestock units (TLUs), which are also applicable to South Africa. The conversation factors used were also used by Peden *et al.* (2007).

Membership to farm association: The study included institutional variables to account for differential access to basic social and agricultural services. According to Muchiri (2013), farmer associations are producer groups or cooperatives which provide services to their members and represent their members' interests with other stakeholders, including agricultural policymakers, business partners and development projects. Farmer associations should effectively represent their members and advise them on farming enterprises (Wynberg *et al.,* 2012) and are increasingly being asked to play a central role in driving agricultural transformation processes in Sub-Saharan Africa, despite their mixed record of success (Nyang *et al.,* 2010). The association represents some form of social capital and can serve as a forum for disseminating important agricultural information.

Participation in scheme management: Participation in scheme management was also looked at from a gender perspective. In most developing countries, despite women's undertaking a large part of the agricultural work (IFAD, 2010); their role in agriculture remains largely unrecognized at both local and national levels. One reason is that, usually there are not enough women in leadership positions in rural producer organizations.

3.3: Research design and data requirement

The study used both primary and secondary data. Primary data were collected using structured questionnaires and key informant interviews (See Appendix A for the questionnaire and Appendix B for the key informant interview guide). The questionnaire, administered on a randomly selected sample of farmers, collected primary data on farm household level characteristics, major crops grown, maize production systems and input and output prices for the crops grown. The secondary data gathered from the key informants was on general enterprise profitability, maize production systems and the functioning of input and output markets. The data was analyzed using the STATA and LINDO computer programmes.

3.4: Sampling technique and sample size

Random sampling was used to select respondents. A list of irrigation farmers was obtained from Mjindi, a parastatal company providing agricultural extension services to smallholder farmers. From 314 smallholder irrigation farmers, a sample size of 150 farmers was selected randomly, which represents 47.78 percent of the farmers. The irrigation scheme has 6 blocks and 25 farmers were randomly selected from each block. All the selected farmers were interviewed. Since the population is largely homogenous, this sample size was large enough to provide reliable data for the study.

3.5: Data collection

As part of the fieldwork preparation, the questionnaire was pretested in Makhathini flats irrigation scheme. Pretesting of the questionnaire was done to five farmers. Pretesting was a process to improve the questionnaire. The main aim was to assess whether the questionnaire was relevant and that respondents could understand the questions, in terms of the concepts, the way the questions were phrased and improving translation of the questionnaire to the local language and any impediments to the instrument's ability to collect the required data economically and systematically. Possible responses that not captured in the closed ended questions were added to reduce the number of responses getting to 'other'. Based on the findings of this process, the questionnaire was restructured and some items were modified to make them clearer.

After pretesting and correction of the questionnaire, a date for the inception of data collection was set. Field research assistants selected from local agricultural extension office and trained about the study before the scheduled interviews with the farmers. They were trained on the contents of the questionnaire, its interpretation, data recording, general behaviour and personal security during the survey.

3.6: Data processing and analysis

In order to achieve the objectives of this study, the following analytical tools were employed:

(1) Descriptive Statistics
(1) Heckman two-step regression model
(2) Gross Margin Budgeting
(3) Linear Programming Model

Most of the variables discussed in this section (Table 3.1) are clear in their derivation, except household size in adult equivalents and total livestock units, which need clarification on their generation. Instead of using household and livestock sizes in numbers, scales presented in the appendices were used to adjust household sizes to reflect the actual labour and the tropical livestock units available per each household. NRS (1989), cited in Wale (2004) and Peden *et al.* (2007) also used these conversation factors.

3.6.1: Descriptive techniques

Descriptive statistics employed to summarise data gathered from farmers in answering objectives one, two and three. Descriptive statistics analysed data gathered on the effects of household characteristics on the decision to grow and the ratio of land under green maize. It also explained the competitiveness of green maize production. It involves the use of percentages, figures, means, t-tests and chi-square tests. Bamire *et al.* (2010) used descriptive statistics characterization of maize producing households in the dry savannah of Nigeria.

3.6.2: Econometric analysis

The study performed some econometric analysis to determine factors affecting the decision to grow green maize and the proportion of land allocated to green maize to total area owned by farmers.

Regression model

Since the response to growing green maize variable is binary, thus the nature of dependent variable, (yes/no), using ordinary least squares (OLS) regression is inadequate when the dependent variable is discrete. If there are no restrictions placed on the values of the independent variables, the predicted values of the outcome variables may possibly exceed either of the limiting values of 1 or 0 (Green, 2003; Montshwe, 2006). The classical regression assumption of heteroscedasticity of the error term is also likely to be violated, especially if the proportions in the total sample are close to either 0 or 1 (Madalla, 1983). If the dependent variable for any given individual must be either 0 or 1, and yet explanatory variable may vary continuously, then the disturbance term cannot be normal and will of necessity be a function of explanatory variable, contrary to the assumptions required by ordinary least square (Gujarati, 2004). Given the violation of the classical regression assumptions, OLS was not used for estimating the model.

There are alternative models used in modelling the relationship between a categorical dependent variable and a set of independent variables. These include Logit, Probit and Tobit (Montshwe, 2006). Also considering that in the particular study, two mutually exclusive decisions had to be made, that is the decision to grow green maize and then deciding how much proportion of land to allocate to the crop, the econometric analysis was split into two steps. First, the study analysed the factors that affect the decision to grow green maize, secondly, the factors that affect how much land is allocated for green maize production by farmers who decide to grow the crop. This then necessitated the use of the Heckman two-step regression model. Chirwa and Matita (2012) and Asres *et al.* (2013) also used the Heckman two-step regression model and noted that results were more reliable as compared to OLS results.

The idea of analysing these factors separately is supported by the argument of Humphreys (2013) who indicated that the two decisions must be independently estimated. Bellemare and Barrett (2006) assumed sequential choice and in their case, they indicated that households initially decide whether or not to participate in the market, and then decide on the volume to purchase or sell, conditional on having chosen market participation. In the current study, farmers initially had to decide to grow green maize, and then decide on the proportion of land to be allocated to the crop. Thus in the current study the proportion of land allocated to green maize has to be analysed separately from the decision to grow green maize. The decision to grow green maize is estimated by a probit model for the probability of observing a positive dependent variable, followed by a Tobit model on the sub-sample of positive observations on growing green maize.

From this background, to address the possible sample selection bias, the study employed the Heckman two-step model. This model is widely for dealing with selection bias (Asres *et al.,* 2013). The Heckman correction, a two-step statistical approach, offers a means of correcting for non-randomly selected samples (Wooldridge, 2010). The model can be specified in two steps as follows:

Selection equation:

$t_i^* = Z_i \gamma + \nu_i$ ……………………………………………………………………… [1]

$t_i = 1$ if $t_i^* > 0$ and $t_i = 0$ otherwise

Where t_i^* is the latent endogenous variable, which is, growing green maize; ν is error term of the selection equation; Z_i is a set of exogenous variables predicting the selection of households growing green maize; $t_i = 1$ denotes growing green maize and $t_i = 0$ denotes non-green maize growers. The choice of the explanatory variables included in Z is guided by literature on household level characteristics affecting crop choice or farm enterprise mix or combinations. The selection equation is used to generate a selection variable (Inverse Mills Ratio) which, when included in the second stage, makes the estimates unbiased and consistent.

In the second stage, the study considered factors associated with the proportion of land allocated to green maize while controlling for selection bias. This was estimated using the Tobit model where the dependent variable was the proportion of land allocated to green maize out of the total land the farmer owns. The value of the proportion of land allocated to green maize varies from 0 to 1, where 0 implies that the farmers does not allocate any land to green maize production (does not grow green maize) while a value of 1 implies that the farmer allocates all his or her land to green maize. The study estimated the model as follows:

Outcome equation:

$y_i^* = \beta x_i + \beta_\lambda \lambda_i + \varepsilon_i$ ……………………………………………………………………… [2]

y_i^* is the proportion of the amount of green maize area to the total area owned by the farmer. This proportion is chosen as the dependent variable and is only observed when the farmer grows green maize. The amount of green maize area is not directly chosen as the dependent variable since it also depends on the total amount of land area the farmer owns. χ is a vector of independent variables (household and institutional characteristics) influencing the proportion of land allocated to green maize, β is the corresponding parameter vector. A positive β will be for variables associated with an increase on the proportion of land under green maize and a negative β will be for variables associated with decrease on the proportion of land under green maize. λ is the inverse Mills ratio generated from equation [1] and ε is a vector of error terms where $\varepsilon \sim N[0, \sigma_{\varepsilon}{}^{2}]$. The model thus takes into account that the dependent variable is non-negative. The green maize land proportion was generated by dividing the area under green maize over the total area that a farmer owns. This was found necessary to use land proportion because the area under green maize was a dependent of the total area a farmer owns.

After running the Heckman two-step model, marginal effects were also generated. The marginal effects indicate how much the probability of observing a one unit increase with a one unit change in the explanatory variable (Humphreys, 2013). Marginal effects provide a more precise picture of the relationship between the explanatory variables and dependent variable (Stallone, 2011).

Statistical and specification tests on model

Before executing the final model regressions, all the hypothesized explanatory variables were checked for the existence of statistical problems such as multicollinearity. Multicollinearity may arise due to a linear relationship among explanatory variables and the problem might cause the estimated regression coefficients to have wrong signs, smaller t-ratios for many variables in the regression and high R^2 value. Besides, it causes large variance and standard error with a wide confidence interval. Hence, it is quite difficult to estimate accurately the effect of each variable (Gujarati, 2004; Woodridge, 2002).

However, despite the difficulty to estimate accurately the effect of each variable, different methods are suggested for detecting the existence of multicollinearity problem between the model explanatory variables. Among these methods, variance inflation factor (VIF) technique is commonly used (Gujarati, 2004) and was also employed in this study to detect multicollinearity problem among the explanatory variables.

Similarly, to determine whether the chosen model has estimated effects of interest, *β,* robustness checks were carried by dropping and or adding variables. Robustness checks have a fundamental role in statistical theory (King and Roberts, 2012). Robustness is necessary for valid causal inference, in that the coefficients of the critical core-variables should be insensitive to adding or dropping variables (White and Lu, 2010). Also to cater for heteroskedasticity, robust standard errors were used.

3.6.3: Gross margin analysis

The general gross margin budget calculation used is:

GM = GI - TVC

Where: GM = Gross Margin (R/ha).

GI = Gross Income (R/ha).

TVC = Total Variable Cost (R/ha).

For this study, data was analysed using the gross margin budgetary techniques specified as:

Where: GM = $\sum_{i=1}^{n} P_i Q_i - \sum_{j=1}^{n} P_j X_j$ ………………………………………….. [3]

GI = Price of Output (P_i) x Quantity of Output (Q_i)

$\sum_{j=1}^{n} P_j X_j = TVC =$ Price of Input (P_j) x Quantity of Input (X_j)

i is the number of respondents (*i* = 1,2,3,…n);

$$\sum_{i=j}^{n} P_j X_j = C_{rj} + C_{sj}Q_{sj} + C_{lj} + C_{fj}Q_{fj} + C_{aj}Q_{aj} + L_j + M_j + T_j$$

Where: C_{rj} = average cost of land rental per season;

C_{sj} = average cost of seed for planting (R);

Q_{sj} = average quantity of seed used for plating (kg/ha);

C_{lj} = average cost of land preparation (R/ha);

C_{fj} = average cost of fertiliser used in planting (R);

Q_{fj} = average quantity of fertiliser used in planting (kg/ha);

C_{aj} = average cost of agrochemicals used (R/ha);

Q_{qj} = average quantity of agrochemicals used (Kg/ha);

L_j = average cost of labour used in all crop agronomic practices (R/ha);

M_j = average cost of marketing crop output (R/ha output);

T_j = average cost of transporting crop output (R/ha output).

The components of the “Total Variable Costs” were cost of seed, fertiliser, and land rental, labour for agronomic practices, irrigation, harvesting and marketing cost.

3.6.4: Linear Programming model

Linear programming (LP) was used to address the third objective. Technically, linear programming may be formally defined as a method of optimising (that is maximising or minimising) a linear function with a number of constraints or limitations expressed in the form of inequalities (Sivarethinamohan, 2008). The general LP model used for this study is a gross margin maximisation model designed to find out the optimum solutions and maximise an objective function from various crop combinations which maximises the returns. The objective is to maximise farm profits and the model was mathematically expressed as follows:

Maximize Z = $\sum p_j x_j$ .... [4]

Subject to: $\sum c_{ij} x_j \leq b_j$ .... [5]

$x_j \geq 0$ ....*Non-negativity assumption*

Where: $i = 1, 2 \ldots m$;

$j = 1, 2 \ldots n$.

Model development:

Here, equation [4] describes the profit expected from farm activities based on resource constrain equation [5], which is further broken down as follows:

Max Gross Margins: Z = $\sum_{j=i}^{n} p_j x_j$ [$j = 1, 2, 3, \ldots n$]

Subject to: $\sum_{j=i}^{n} c_{ij} x_j \leq b_j$

$\sum_{j=i}^{n} a_{ij} x_j \leq a_i$ .... Land size constraint

$\sum_{j=i}^{n} b_{ij} x_j \leq b_i$ .... Land rental cost constraint

$\sum_{j=i}^{n} c_{ij} x_j \leq c_i$ .... Land preparation cost constraint

$\sum_{j=i}^{n} d_{ij} x_j \leq d_i$ .... Labour constraint

$\sum_{j=i}^{n} e_{ij} x_j \leq e_i$ .... Seed cost constraint

$\sum_{j=i}^{n} f_{ij} x_j \leq f_i$ ………………………………. Fertiliser constraint

$\sum_{j=i}^{n} g_{ij} x_j \leq g_i$ ……………………………. Agrochemicals constraint

$\sum_{j=i}^{n} h_{ij} x_j \leq h_i$ ………………………………. Irrigation constraint

$\sum_{j=i}^{n} k_{ij} x_j \leq k_i$ ………………………………. Harvesting constraint

$\sum_{j=i}^{n} l_{ij} x_j \leq l_i$ ………………………………… Marketing constraint

$x_j \geq 0$ ……………………………………… *Non-negativity assumption*

Where:

Z	=	Objective function;
x_j	=	Area under the *j*th crop production activity;
p_j	=	Gross margin per ha of the *j*th crop activity;
a_{ij}	=	Land coefficient of the *j*th crop;
b_{ij}	=	Land rental cost for the *j*th crop activity;
c_{ij}	=	Land preparation cost for the *j*th crop activity;
d_{ij}	=	Labour requirements for the *j*th crop activity;
e_{ij}	=	Seed cost requirement for the *j*th crop activity;
f_{ij}	=	Fertiliser cost requirement for the jth crop activity;
g_{ij}	=	Agrochemicals cost requirement for the *j*th crop activity;
h_{ij}	=	Irrigation cost requirements for the *j*th crop activity;
k_{ij}	=	Harvesting cost requirements for the *j*th crop activity;
l_{ij}	=	Marketing cost requirements for the *j*th crop activity;
a_i	=	Available land in hectares;
b_i	=	Available money for land rental;
c_i	=	Available money for land preparation;
d_i	=	Available labour;

e_i	=	Available money for crop seed;
f_i	=	Available fertiliser in tons;
g_i	=	Available money for agrochemicals;
h_i	=	Available money for irrigation;
k_i	=	Available money for harvesting;
l_i	=	Available money for marketing;
n	=	Number of crop production activities.

3.7: Chapter summary

Both primary and secondary data was used in this study. The primary data was gathered from Makhathini flats irrigation scheme farmers. Secondary data was obtained from key informants like the agricultural extension officers working with the farmers. The secondary data gathered from the key informants was on crop enterprises, maize production systems and the efficiency of input and output markets. A total of 150 farmers participating at Makhathini irrigation scheme were interviewed. The survey questions covered aspects on the farmers' household characteristics, major crops grown, maize production systems, input and output market prices and marketing of farm produce.

CHAPTER 4: RESULTS AND DISCUSSION

4.1: Introduction

This chapter presents the main findings of the study. In the next section, the chapter presents the household demographics, maize production systems in Makhathini flats irrigation scheme, and socio-economic characteristics of farmers. The second section will present the regression results of the factors determining the choice and proportion of land allocated to green maize production. The chapter will end with the gross margin and LP analysis of the crops grown in Makhathini.

4.2: Household demographics and socio-economic characteristics

The total number of farmers randomly selected is 150, all of them farming in Makhathini flats irrigation scheme. Tables 4.1 and 4.2 show the descriptive statistics of the data gathered from the study. Statistics are discussed below.

Age: Elderly farmers, whose average age is 46.35 years, dominated the irrigation scheme. The average farming experience in the scheme is 10 years. The dominance of middle-aged working class can be attributed to Makhathini area being comprised of farming communities with very few other professions available to absorb this working class. The Umkhanyakude economy, of which Makhathini Flats is part of, depends largely on agriculture, with a small manufacturing sector (Moenisa, 2004).

The average age and gender of farmers indicates ageing farmers, and the scheme is female-dominated. An aging population of farmers in Makhathini Flats implies that the irrigation scheme could gradually crumble as the remaining farmers progressively work themselves to retirement. Berry, (2009) noted that in African policy debates it is often assumed that rejection of agriculture by rural young people and their migration to urban areas are the primary causes of the aging farm population.

Household size: A mean household size of five members was recorded. To cater for the limitations in assessing household's labour endowment using household size in numbers, where young children and elders are counted but cannot carry farm tasks, household size in adult equivalents were generated using recommended conversion factors, also used by NRS (1989), and cited in Wale (2004). In the current study, a mean household size equivalent of 3.92 members was recorded (Table 4.1). Jozini Municipality Report, (2004) reported almost the same average household size equivalents of 4.70 members in the area.

Table 4.1: Characteristics of farm households in Makhathini (Continuous variables)

Variable definition			
Continuous variables		*Mean*	*Std. deviation*
Age of household head		46.35	9.41
Household size:	Numbers	5.32	2.53
	Adult equivalents	3.92	2.04
Educational level of household head:	Male	2.08	0.81
	Female	2.05	0.81
Livestock owned:	Cattle	4.11	3.79
	Sheep and goats	12.84	9.48
	Poultry	23.02	15.23
Tropical livestock units (TLUs)		4.01	4.27
Total plot size (ha)		5.20	4.72
Years of farming in the scheme		10.04	7.59
Area under green maize (ha):	Summer 2012/13 season	2.07	1.23
	Winter 2013 season	2.12	1.93
Value of farm assets (ZAR)		139 472.58	113 752.86

n = 150

Source: Farm survey (2013)

Education: The household heads in the sample did not achieve high levels of education, with an average of 2.06 years of education (Table 4.1). High illiteracy levels exist among the household heads. Dearlove (2007), Mnkeni *et al*. (2010) and Gouse *et al.* (2005) got similar findings. STATSSA, (2004) indicated that approximately 46 percent of the Jozini residents have no education, while 9 percent have completed Grade 12, with only 4 percent having attended tertiary institutions.

Livestock: The livestock herd sizes in Table 4.1 close to the 3.18 reported by Sinyolo (2012) in Tugela Ferry irrigation scheme, which is also in KZN. Lankford *et al.* (2010) also noted that 30 percent of households on the Pongola floodplain keep livestock, especially cattle, however the current study results from Makhathini flats irrigation scheme, which is under Pongola flood plain shows that 51.3 percent households owns cattle.

Area allocated to green maize: Out of the sampled farmers, 84.7 percent of them grow green maize in winter (2013 season) and 36.7 percent grow green maize in summer (2012/13 season). This shows that 23 farmers do not grow green maize in winter 2013 season, whilst 95 farmers do not grow the crop in summer 2012/13 summer season. Most of the farmers who do not grow green maize allocate high proportion of their land to sugarcane production with small pieces of land which is left for growing family food crops, However some farmers grow the crop in both seasons, some even grow a third green maize crop in a year. The area allocated to green maize in winter and summer is different, with more area planted in winter than in summer (Table 4.1). This difference in area allocated to green maize may be attributed to the fact that during summer a number of farmers outside the irrigation scheme, which constitute part of the green maize market in winter, also grow the crop under rain-fed system, leading to many irrigation farmers receiving low prices for their cobs.

Table 4.2: Characteristics of farm households in Makhathini (Categorical Variables)

Definition of Categorical variables		***Percentage***
Household head marital status:	Single	10.0
	Married	56.7
	Divorced	20.6
	Widowed	12.7
Household that are male-headed		41.3
Plot owners		53.3
Farmers growing green maize:	Summer 2012/13 season	36.7
	Winter 2013 season	84.7
Farmers with access to extension services		66.0
Farmers with access to agricultural credit		34.7
Farmers who are members of association		82.6
Farmers involved in scheme management		31.3

n = 150

Source: Farm survey (2013)

Gender: Table 4.2 indicates that 41.3 percent of the household heads were male-headed and 58.7 percent were female-headed. Jozini Municipality Report, (2004) reported that 53.7 percent of households in Jozini are female -headed, which agrees with the results in this study.

Land ownership status: Some 53.3 percent of farmers own the plots whilst 46.7 percent rent from those who own land (Table 4.1). The study also looked at land ownership status from a gender point of view. ActionAid (2011) suggests that most women do not own the land they farm as customary practices and legal provisions limit their access to land and other productive assets. Sanchez *et al.* (2005) also added that women own only 1 per cent of the land in Africa. In the current study, the χ^2 tests revealed that there is significance difference on plot ownership between males and females (p<0.01) (Table 4.3). This shows gender imbalance on land access in Makhathini Flats irrigation scheme can imply low agricultural production from women as they lack production assets.

Table 4.3: Gender and plot ownership status

		Plot ownership status			χ^2 significance level
		Yes	No	Total	
Gender:	Male	41	21	62	
		66.1%	33.9%		
	Female	39	49	88	***
		44.3%	55.7%		
	Total	**80**	**70**	**150 = *n***	

Source: Farmer Survey (2013).

Note: ***: Statistically significant at 1% confidence level.

The development of African communities was biased towards men when giving production resources (Adeniyi, 2010), and this can explain the inequality in land ownership between male and female farmers in Makhathini. Adeniyi (2010) also came to the same conclusions when he indicated that women generally own less land in South Africa. The results are also in line to those of Quisumbing and Pandolfelli (2008) who concluded that women are often disadvantaged in both statutory and customary land ownership. The study result suggests a need to policy intervention to enable women to increase their access to and control over land.

Extension: Some 66 percent farmers receive agricultural extension services (Table 4.2). Mjindi and the local government agricultural extension provides agricultural extension services and farmers receive government distributed inputs (fertiliser, seeds, irrigation equipment and agro-chemicals) and training programmes from the government Department of Agriculture.

Key informants revealed that diffusion of information takes place mainly through formal extension services. Key informants revealed that formal extension is changing from traditional top-down, male-dominated approaches, to gender-sensitive, demand-driven approaches focusing on broader, interrelated issues and facilitation. However, it was unclear to them how these reforms have affected women's access to extension in Makhathini. The study showed that there is no significant difference in access to agricultural extension services between males and females (Table 4.4).

Table 4.4: Gender and access to extension services

		Access to extension services		Total	χ^2 significance level
		Yes	**No**		
Gender:	Male	41	19	60	
		68.3%	31.7%		
	Female	58	27	85	**n.s.**
		68.2%	31.8%		
	Total	**99**	**46**	**145 = *n***	

Source: Farmer Survey (2013).

Note: n.s: = not statistically significant.

Credit: Credit was not widely used as only 34.7 percent farmers used it. This can be attributed to the fact that most of the irrigation farmers had defaulted loan repayments before. Strauss (2005) on his study in Makhathini reported that around 80 percent of farmers have defaulted on their loans. Also the high risks associated with smallholder agriculture lending makes lending agencies cautious about lending to them.

The study also looked at credit access by gender. Quisumbing and Pandolfelli (2008) concluded that the majority of financial institutions are loath to lend to smallholder farmers, especially female farmers who usually lack collateral security. Chirwa (2005) also concluded that the poverty profile in Africa reveals that female-headed households tend to be poorer and more resource constrained, which may affect their access to credit. Some 43.5 percent and 29.4 percent of males and females farmers respectively had access to credit and the difference is statistically significant (Table 4.5). Sanchez *et al.* (2005) noted that in Africa females has less access to agricultural credit than males. Similarly, Theobald (2013) noted institutional and cultural barriers facing women, including lack of access to land, which normally affects credit access.

Table 4.5: Gender and access to agricultural credit

		Access to agricultural credit		Total	χ^2 significance level
		Yes	**No**		
Gender:	Male	27	35	**62**	
		43.5%	56.5%		
	Female	25	60	**85**	*
		29.4%	70.6%		
	Total	**52**	**95**	**147 = *n***	

Source: Farmer Survey (2013).

Note: *: Statistically significant at 10% confidence level.

This difference in access to credit can be related to capital endowments, which are generally better for male farmers than female farmers.

Membership to farmer association: Out of 124 farmers who indicated to be members of farmer associations, 63.7 percent were females whilst 36.3 percent were males and there is a significant difference between male and female members across membership ($p<0.01$) (Table 4.6). This is probably because of women's dominance in the irrigation scheme as shown in Table 4.1. These females valued traditional forms of collectivism and join the association based on volunteerism and mutual trust.

Table 4.6: Gender and membership to farm association

		Membership to farm association		Total	χ^2 significance level
		Yes	**No**		
Gender:	Male	45	17	**62**	
		84.9 %	15.1%		
	Female	79	8	**87**	**
		90.8%	9.2%		
	Total	**124**	**25**	**149 = *n***	

Source: Farmer Survey (2013).

Note: **: Statistically significant at 5% confidence level.

Sibanda (2012) and IFAD (2010) came to the same conclusion of women's dominance in smallholder farming in Sub-Sahara and that they undertake a large part of the agricultural work.

Farmers involved in scheme management: Results reveal that more females participated in the management of the scheme. Out of 82.6 percent farmers who are members of farmer associations, 37.9 percent participated in scheme management (Table 4.7). However, there was no significant difference on gender participation in scheme management. This shows that although women participated in farmer associations' management but they did not dominate in managerial structures (Table 4.7). The result is contrary to those reported by Quisumbing and Pandolfelli (2008) on African smallholder farming associations, which states that females are often isolated from governance structures and are rarely represented in local and national fora. However more resources can be invested to increase the capacity of farmer organisations and empower women, and to strengthen women's leadership. This is because effective women representation in farmer organizations can provide a powerful instrument to make women's voices heard, so that they can influence over decisions that affect their farming and livelihoods.

Table 4.7: Gender and participation in scheme management

		Farmers in scheme management			
		Yes	**No**	**Total**	χ^2 **significance level**
Gender:	Male	18	35	**53**	
		35.3%	64.7%		
	Female	29	54	**83**	**n.s.**
		34.1%	65.9%		
	Total	**47**	**89**	**136 = *n***	

Source: Farmer Survey (2013).

Note: n.s: = not statistically significant.

4.3: Crops grown in Makhathini Flats irrigation scheme

Apart from green maize, there are other crops which are commonly grown in Makhathini and Table 4.8 shows the area allocated to these crops during the 2012/13 summer season and 2013 winter season. There is diversity in crops grown in the scheme. The major crops grown are sugarcane, green maize, cabbages, butternuts and Irish potatoes. Key informants indicated that usually there is no fallowing of land in Makhathini. Land use changes with seasons in the form of crop rotation and in response to produce market availability and profitability.

Table 4.8: Area (ha) under crops grown in Makhathini Flats

Crop	Minimum	Maximum	Mean	Std. Deviation
Summer 2012/13 season				
Sugarcane	1.00	15.0	5.48	3.20
Green maize	0.20	5.00	2.07	1.23
Cabbages	0.20	4.30	1.62	1.00
Butternuts	0.50	3.00	1.20	0.75
Irish potatoes	0.40	2.00	1.06	0.69
Winter 2013 season				
Sugarcane	1.00	15.0	5.48	3.20
Green maize	0.20	5.00	2.12	1.93
Cabbages	0.95	4.13	1.40	0.87
Butternuts	0.55	3.40	1.27	0.79
Irish potatoes	0.32	2.13	0.83	0.61

Source: Farm survey (2013).

4.4: Green maize production system in Makhathini Flats irrigation scheme

Farmers practice mixed-cropping of maize, vegetables, beans, butternuts and sugarcane. The summer green maize crop is grown from November to February whilst the winter crop is grown from April to August. Farmers, who indicated growing the third green maize crop, grow it soon after harvesting the second one, which is in July/August and it is usually harvested in October/November. The need for land preparation for the summer season means that only a limited area can be planted with a third season green maize crop. The small output fetches a higher price.

Out of the 84.6 percent farmers who indicated to be growing green maize, 99.2 percent used hybrid seed and 0.8 percent use retained seed. The results are in line with those of Gouse *et al.* (2008) who reported the high use of hybrid seeds in Makhathini. The use of hybrid seed for green maize in Makhathini supports the observation of Van Averbeke (2008), indicating that farmers in Limpopo maximise the number of marketable cobs per unit area through cultivar selection. For this reason ETZ 200 and SC 701 were identified as superior cultivars in terms of cob length. SeedCo and Pannar varieties are commonly grown for green maize.

4.4.1: Land preparation and maize crop management practices in Makhathini Flats

The green maize agronomic practices at Makhathini are described here from land preparation up to harvesting the green cobs for the market. Farmers carry out land preparation using government tractors stationed at Mjindi and the local agricultural extension office at a charge. Some 8.5 percent and 10 percent of farmers use hired labour and family labour respectively for land preparation. Some farmers who own tractors and private contractors also provide land preparation services. Farmers indicated that private contractors provide their services at short notice whilst the scheme tractors had a long waiting period, which can interfere with optimum land preparation and planting dates.

Green maize planting in Makhathini is done manually either using family or hired labour. Some 0.8 percent of interviewed farmers used mechanical methods whilst 89.2 percent used hired labour and 10 percent used family labour. However, a combination of hired labour and family is also practiced when the household does not have enough family labour to carry the operation.

Key informants suggested that for both winter and summer season green maize crop, spacing ranges from 75 cm by 30 cm to 90 cm by 35 cm. No standard spacing was used. However since hawkers use cob size as one of the main criteria for the selection of green cobs, farmers seeking to sell green maize cobs benefit from adjusting their practices, especially planting density that produce cobs that make the size grade. This is in line with the spacing reported by Van Averbeke (2008) at Dzindi irrigation scheme, that the optimum planting density for green maize production using the cultivar SC 701 was about 4.0 plants m^{-2}, but planting density has to be reduced to about 3.0 plants m^{-2} when using the PAN 93 cultivar. This implies that to have bigger cobs which are marketable, green maize production requires more plant spacing than grain maize production.

Weeding of the crop is mainly done using hired labour (82.9 percent), followed by family labour with 11.7 percent. Mechanical weed control is not widely used, however farmers apply post emergence herbicides using knapsack sprayers and later followed by manual weeding using hand hoes. Weeding is done twice, first at vegetative stage and secondly at tasselling stage, though farmers indicated that they can delay the operation even up to second dour stage depending on weed infestation in the field.

Fertilisers are applied twice, as basal and top dressing and the application rates are diverse, probably dictated by the farmers’ fertiliser endowment. However, a range of 200kg-300kg per hectare for both basal and top dressing fertilisers is used. While 99.2 percent of the farmers reported use of chemical fertiliser at planting, no use of manure was recorded. Much of the fertiliser application is done by hired labour as indicated by a high proportion of 80 percent as compared to the use of family labour, which is only 20 percent.

Chemical control for pest, though considered very effective was not widely used. Farmers indicated that it is expensive. In addition to the cost implication, farmers indicated that they don't use chemicals because of the residual effects of pesticides as they would want to sell the maize stover to livestock farmers, who usually prefer maize stover that was not sprayed with chemicals before. The key informants added that some farmers with smaller plots can even use cultural methods of stem borer control like wood ash and soil and farmers indicated that it is effective. Hired labour constitutes 71.2 percent of the total labour used on pests and disease control whilst family labour constitutes 28.8 percent.

Table 4.9: Methods and sources of labour for green maize production in Makhathini

Operation	**Percentage (%) contribution in carrying operation**			
	Mechanically	**Chemically**	**Hired labour**	**Family labour**
Land preparation	81.5		8.50	10.0
Planting	0.8		89.2	10.0
Weeding	2.3	3.1	82.9	11.7
Fertiliser application			80.0	20.0
Pest and disease control			71.2	28.8
Irrigation			68.0	32.0
Harvesting			92.1	7.90

Source: Farmer Survey (2013).

Sprinkler irrigation system is used. Irrigation of crops is mainly done by hired labour, with 68 percent hired labour contribution on green maize irrigation. Key informants indicated that no systematic irrigation scheduling is followed and as such farmers tend to over irrigate crops. This was attributed to poor knowledge of crop water requirements, yield responses to water, financial and economic implications of over irrigating. This is consistent with the observation of Tariq and Usman (2009) that despite of the fact that irrigation scheduling is a decision making process, very few farmers understand it.

As indicated in Table 4.8, the results show that 92.1 percent of green maize harvesting is done by hired labour whilst 7.9 percent is done by family labour.

In green maize production, it was noted that there were two types of agronomic operations in which hired labour is commonly used. These operations which required more labour are land preparation, planting, weeding and harvesting. For these operations, hired labour is frequently sought both by households that had enough capital to pay for labour and or are labour-deficient, such as female-headed households and elderly persons, who could not fulfil these strenuous operations. For sugarcane and potatoes, farmers indicated that they rely much on hired labour as family labour is not enough for planting and harvesting operations. However, for cabbages and butternuts, farmers indicated that the main source of labour is from family members and sometimes the only source of labour employed by resource-poor farmers depending on plot size. Labour exchanges among relatives also occur. In most cases such labour exchange are used for farm tasks that required huge amounts labour at a given time, such as weeding. However, the contribution of exchanged labour to a family's overall labour input was low (less than 5 percent).

In summary, green maize is produced in both seasons, with more land being allocated to the crop in winter than in summer. Women dominate in green maize production and farmers averages 46.35 years old. There is high use of hybrid seed, inorganic fertilisers and the crop is grown in rotation with other crops. Sugarcane is grown as an annual crop whilst cabbages, butternuts and potatoes are grown in both seasons but mainly in summer.

4.5: Gender and farming in Makhathini Flats irrigation scheme

The study also looked at farmers in the scheme from a gender point of view. The results showed number of differences on household characteristics disaggregated by gender. T-tests were carried to determine whether the observed differences are statistically significant. The means, standard deviations and t-statistic significance levels of the variables listed across gender in Makhathini Flats irrigation scheme are presented in Table 4.10. Only years of farming in the scheme and the total plot size were statistically significant between males and females ($p<0.10$).

The recorded total land size varies considerably with some farmers owning less than a hectare whilst others owning plot sizes of 10.37 ha. The significant difference on total plot size across gender supports the widely reported phenomenon on women's limited access to land in Africa. Figures from the UN Food and Agriculture Organisation (FAO, 1995) cited in ActionAid (2011), point out that women own smaller and less fertile land holdings than men. The results are supported by Bragg *et al.* (2008) who concluded that access to land depends on the distribution of power in custom or law -women in particular often lack power to access land.

Table 4.10: T-tests for gender dynamics in Makhathini Flats irrigation scheme

Variable	**Male**		**Female**		**T-test**	**Total**	
	Mean	**SD**	**Mean**	**SD**		**Mean**	**SD**
Age	45.82	8.28	46.73	9.79	n.s.	46.35	9.41
Education	2.08	0.68	2.05	0.76	n.s.	2.06	0.72
Household size: numbers	5.10	2.64	5.47	2.45	n.s.	5.32	2.53
:adult equivalents	3.75	2.12	4.04	1.99	n.s.	3.92	2.04
TLUs	4.48	3.72	4.12	4.64	n.s.	4.27	4.27
Years of farming	11.63	8.54	8.50	6.26	*	10.04	7.59
Total plot size	6.00	5.22	4.63	4.27	*	5.20	4.72
Area under green maize:							
:Winter 2013 season	2.00	1.78	2.31	2.06	n.s.	2.12	1.93
:Summer 2012/13 season	1.97	1.00	2.14	1.38	n.s.	2.07	1.23

Source: Farmer Survey (2013).

Note: *: = Statistically significant at 10% confidence level.
n.s: = not statistically significant

Table 4.11 shows that in terms of numbers, more females than males are into green maize production. This can be related to the dominance of females in the irrigation scheme as they constituted 58.7 percent of farmers in the scheme (Table 4.2).

Table 4.11: Gender ad green maize production

		Green maize production			
		Yes	**No**	**Total**	**χ^2 significance level**
Gender:	Male	51	11	**62**	
		82.2%	17.8%		
	Female	70	18	**88**	**n.s.**
		79.5%	20.5%		
	Total	**121**	**29**	**150 = *n***	

Source: Farmer Survey (2013).

Note: n.s: = not statistically significant

Although area allocated to green maize production by females was greater than area allocated by males (Table 4.10), their dominance both in numbers and area allocated to the crop is not statistically significant as revealed by the t-test result in Table 4.10 and chi -square test result in Table 4.11. Significance differences were noted on plot ownership status, credit access, membership to farm association, years of farming and plot size. All other differences with respect to gender were not statistically significant.

4.6: Factors affecting the decision to grow and proportion of land allocated to green maize

The Heckman two-step procedure was used for analysing the factors affecting the decision to grow green maize and the proportion of land put under the crop to the total amount of land area owned by a farmer. The first is the Probit model, with probability estimates of the decision to grow green maize followed by the Tobit model, which determines the proportion of land allocated to green maize out of the total area the farmer owns.

Before running the Probit model, an OLS model was run to test for multicollinearity and the correlation matrix was also generated to see correlation coefficients among the variables. A number of variables were significantly correlated with AGE and HSEHOLD_SIZ having the highest correlation coefficient of 0.293 (Appendix J). However, despite this correlation of the chosen variables, there was no problem of multicollinearity. The VIFs for all variables are less than 10 with an average of 1.26 (Appendix K), which indicate that multicollinearity was not a serious problem (Gujarati and Porter, 2010). Robust standard errors were used to correct for heteroscedasticity. All the proposed explanatory variables were included in the final models estimated.

4.6.1: Factors determining decision to plant green maize

The Probit model results (Table 4.12) show that the variables that significantly influenced the probability of growing green maize include age, household size in adult equivalents, plot size, access to extension and green maize gross margins.

The Probit model results show that an increase in age increases the probability of the farmer to grow green maize. This implies that as farmers' age increase by a year, the probability of growing green maize increases by 1.1 percent. Asayehegn *et al.* (2011) also observed that age is an important variable influencing farmers' decisions in smallholder irrigation farming. Household size measured in terms of adult equivalents was positively associated with the decision to grow green maize and the coefficient is statistically significant ($p<0.01$). The marginal effects show that an additional adult member of the household increases the probability of growing green maize by 5.1 percent. The results support Sinyolo *et al.* (2014) and Jaleta *et al.* (2009) who indicated that smallholder farmers rely on family labour and household size influences farming decisions.

As expected, total plot size had a positive significant influence on the decision to grow green maize ($p<0.01$). The results show that as the size of cultivated area increases by a hectare, the probability of growing green maize increases by 2.5 percent. This means that farmers with small pieces of land are less likely to grow green maize. Poulton *et al.* (2001) suggest that land is an important factor influencing farmers' crop production decision. Farmers who had contact with extension officers have an 11.3 percent more chance of growing green maize than their counterparts. This is revealed by a statistically significant relationship between green maize growing and access to extension ($p<0.05$). The positive relationship between support services and farmers in irrigation schemes can also be viewed as the tendency of government support to be concentrated to those households engaged in projects, a common practice by the South African government (Sinyolo, 2013). In Makhathini flats irrigation scheme, Mjindi which provides extension services to irrigation farmers is located next to the irrigation scheme, whilst Department of Agriculture is also in Jozini, working closely with both farmers in the irrigation scheme and rain-fed farmers, making it more convenient to offer support services to all farmers.

As expected, the green maize gross margin positively and significantly influences the decision to grow the crop in the study area ($p<0.10$). The gross margin of the competitive crop (cabbages) has a negative relationship with the decision to grow green maize. However it was not statistically significant. These results differ with findings by Amatayakul and Azar (2008), who pointed out that gross margins of competitive crops might not significantly affect the planting decision of an alternative crop, but other factors such as suitability of land for the competitive crop, expertise and labour availability required for growing the crop.

Table 4.12: Determinants of green maize production: Probit regression results

Independent variables	Coefficients			Marginal Effects		
	Value	Robust St. Error	P>$\|z\|$	Value	St. Error.	P>$\|z\|$
Age	0.063***	0.021	0.003	0.011***	0.004	0.002
Gender	0.001	0.308	1.000	0.001	0.053	1.000
Marital Status	-0.390	0.339	0.251	-0.068	0.059	0.253
Education	0.458	0.342	0.181	0.080	0.058	0.172
Household size (adult equivalents)	0.293***	0.097	0.003	0.051***	0.016	0.001
Plot size (ha)	0.144***	0.042	0.001	0.025***	0.007	0.000
Plot ownership status	0.364	0.310	0.240	0.063	0.054	0.243
Value of farm assets	-0.351	0.464	0.449	-0.061	0.080	0.445
Livestock units	0.012	0.047	0.804	0.002	0.008	0.804
Access to extension	0.649**	0.312	0.038	0.113**	0.053	0.033
Access to credit	0.004	0.342	0.990	0.001	0.059	0.990
Farm association membership	-0.070	0.109	0.522	-0.012	0.019	0.516
Participation in scheme management	0.455	0.338	0.178	0.079	0.058	0.181
Gross margin cabbages	-0.001	0.001	0.207	-2.22e-06	1.77e-06	0.210
Gross margin green maize	0.001*	0.001	0.058	4.58e-06*	2.34e-06	0.050
Constant	-4.376	1.442	0.002			
Wald Chi ^{2} (15)	55***					
Pseudo R ^{2}	0.356					
Log-likelihood function	-47.46					
n	150					

Source: Farmer survey (2013)**.**

Note: ***, ** and * indicate significance at 1%, 5% and 10% levels, respectively.

Although not statistically significant, gender has a positive influence on the decision to green maize. Males are more likely to grow green maize than females. This suggests that females have more constraints in growing green maize, or are committed to other crops than males. A positive, statistically insignificant relationship was noted between levels of education and the decision to grow green maize. Level of education was considered an important variable because it equips farmers with the knowledge to make informed decisions.

4.6.2: Factors determining proportion of land allocated to green maize

The Tobit regression model were used to determine the factors affecting the proportion of the amount of land area of green maize crop to the total amount of land area owned. These estimates are presented in Table 4.13. The marginal effects (ME) measure the changes in the (proportion of land under green maize to the total amount of land area for a unit change of the average value of the independent variable. The results indicate that, collectively all estimated coefficients are statistically significant as reflected by the significant Chi-square value ($p<0.01$) (Table 4.13). This confirms that the model fits the data well. The insignificant λ in the Tobit model indicates that there is no evidence of selection bias at the conventional 10 percent significance level.

Gender of household heads influences the proportion of area allocated to each crop. The result shows that males have a 15.4 percent more chance of increasing the land under green maize production compare to females. This is denoted by a statistically significant value ($p<0.10$) (Table 4.13). Female farmers face a number of constraints, for example, they may only access land through a male relative, and however that access may also entail limitations on the uses of the land such that they will grow mainly food crops for family consumption and not for sale.

A statistically significant relationship was observed between marital status and proportion of land allocated to green maize ($p<0.10$). This implies that married farmers allocate more land to green maize production than single-headed households. This result suggest that single farmers had fewer economically-active household members and are in a disadvantageous position relative to their married counterparts in deploying family labour for farm production. Takane (2008) noted that an analysis of single-headed households sheds some light on the important correlations between labour endowments and agricultural production. Better endowments of labour for married farmers may explain the difference in the proportion of land allocated to green maize production.

Table 4.13: Determinants of proportion of land allocated to green maize production: Tobit regression results

Independent variables	Coefficients			Marginal Effects		
	Value	Robust St. Error	P>$\|t\|$	Value	St. Error.	P>$\|z\|$
Constant	-0.107	0.339	0.753			
Age	0.002	0.004	0.612	0.002	0.004	0.611
Gender	0.154*	0.083	0.064	0.154*	0.083	0.062
Marital Status	0.171*	0.088	0.053	0.171*	0.088	0.051
Education	0.064	0.089	0.476	0.064	0.089	0.475
Household size (adult equivalents)	0.041	0.027	0.125	0.041*	0.027	0.123
Plot size (ha)	-0.062***	0.011	0.000	-0.062***	0.011	0.001
Plot ownership status	0.090	0.080	0.264	0.090	0.080	0.263
Value farm assets	-0.112	0.069	0.109	-0.112	0.069	0.107
Livestock units	0.012	0.009	0.187	0.012	0.009	0.185
Access to extension	0.086	0.088	0.330	0.086	0.088	0.328
Access to credit	0.151*	0.081	0.064	0.151*	0.081	0.062
Participation in scheme management	0.006	0.079	0.934	0.006	0.079	0.934
Gross margin cabbages	-9.00e-06***	3.22e-06	0.006	-9.00e-06***	3.22e-06	0.005
Gross margin green maize	0.001***	5.05e-06	0.001	0.001***	5.05e-06	0.001
Mills ratio (λ)	0.033	0.157	0.832	0.033	0.157	0.832
/sigma (σ)	0.381	0.045	0.753			
Wald Chi ^{2} (15)	118.82***					
Pseudo R ^{2}	0.40					
Log-likelihood function	-88.38					
n	150					

Source: Farm survey (2013).

Note: ***, ** and * indicate significance at 1%, 5% and 10% levels, respectively.

The plot size variable, measured in hectares, which captures the effects of land constraints on the proportion of land allocated to green maize is negative and statistically significant ($p<0.01$). Accordingly, a hectare increase in the size of land owned by a household leads to a decrease in the proportion of land allocated to green maize production by 6.2 percent. The study expected that the proportion of land under green maize to be positively associated with land size. However, this result implies that as the land area increases, farmers increase area under sugarcane production.

Access to credit was positive and significantly related to the proportion of land allocated to green maize ($p<0.10$). The estimates show that farmers who have accessed credit are more likely to increase area under green maize by 15.1 percent. This is because credit access enables smallholder farmers to finance the purchase of inputs and other production equipment, hence encourage farmers to produce a cash crop like green maize. Girabi and Mwakaje (2013) also came to the same conclusion when they indicated that credit access has significant impact on crop acreages under smallholder farmers. However, Pender et al. (2004) report contrasting findings. They found little evidence of the impact of credit access to agricultural intensification and crop production. This may suggest that access to credit by smallholder farmers is important but not sufficient by itself to determine the land put under a crop. It needs other factors to complement credit accessibility in order to increase the proportion of land under cultivation.

The statistical analysis indicates that a unit increase in green maize gross margins relative to competitive crops implies an increase in the proportion of land allocated in favour of green maize. The variable estimate was found to be statistically significant ($p<0.01$). This implies that the higher the gross margins for green maize, the more land is allocated to the crop in the next season, ceteris paribus. This shows that farmers behave rationally to maximize profits from any given farm resources. The gross returns on green maize compared to alternative crops is a key issue for any crop substitution program aimed at increasing farmer's profits. The gross margin of the next competitive crop, which was found to be cabbages, was negatively related and statistically significant ($p<0.01$). As expected, this implies that the proportion of land under green maize production is a decreasing function of cabbages gross margin. This means that as cabbages gross margins increases, the proportion of land allocated to green maize production is likely to decrease as farmers will put more of their land to the most paying crop, ceteris paribus. Again, this is evidence of the economic rationality of smallholder farmers.

4.7: Competitiveness of green maize production in Makhathini Flats irrigation scheme

This section discusses the competitiveness of green maize in comparison to other crops grown in Makhathini. It starts by conducting a comparative analysis of the gross margins crops commonly grown in the area, followed by a profit maximization linear programming model. To deal with heterogeneity of land ownership, the study divided farmers into two groups. The first group of farmers managing up to five hectares, and the second group had more than five hectares of land. The second group of farmers is different from the first one in two major ways. Firstly, they are sugarcane growers and secondly they are the owners of the land. Some of them rent out land to the first group. Mushunje (2005) and Machingura (2007) indicated that land is the most limiting factor in agricultural production of the smallholder farmers and most important asset agricultural societies especially in the rural areas of South Africa. Therefore, considering land as an important factor of production, analysing the competitiveness of crops grown with respect to land size gives realistic results of the crop competitiveness for different farmer groups. The gross margin analysis was carried for both small and large plot-size farmers for both winter and summer seasons. The gross margins were used for developing the linear programming model.

4.7.1: Gross margin analysis

For realistic gross margins, the study uses yields and production costs obtained in the scheme. Input prices for seed, fertilizer and agrochemicals were from survey results. The main components of total variable costs were land preparation, seed, labour, agrochemicals and fertilizers. The gross margins were for each farmer. Each crop gross margin was compared to that of green maize to determine the competitiveness of green maize with respect to other crops grown in Makhathini Flats irrigation scheme.

4.7.2: Gross margin analysis for crops grown in winter

Table 4.14 presents gross margin budgets for winter crops grown by both groups of farmers. The gross margin budgets for farmers with small plots (≤5ha) indicate that amongst the crops grown in winter, cabbage has the highest gross margin followed by green maize, butternuts and Irish potatoes (Table 4.14). The difference between the mean gross margins of green maize and cabbages is statistically significant ($p<0.01$) (Table 4.15). Although cabbage has high production costs as compared to green maize, the gross margin budgets show that cabbage production in Makhathini Flats is a more profitable winter enterprise to green maize.

Table 4.14: Winter crop gross margin budgets

	Winter gross margin for farmers with small plots (≤5ha)				Winter gross margin for farmers with large plots (>5ha)			
	Green Maize (ZAR)	Cabbages (ZAR)	Butternuts (ZAR)	Irish Potatoes (ZAR)	Green Maize (ZAR)	Cabbages (ZAR)	Butternuts (ZAR)	Irish Potatoes (ZAR)
Gross Income	**40 872.00**	**85 323.00**	**44 631.00**	**71 874.60**	**38 928.00**	**86 079.00**	**45 022.5**	**73 240.50**
Seed	1 800.00	6 500.00	1 050.00	14 400.00	1 800.00	7 750.00	1 123.71	12 262.40
Land prep	1 888.40	2 700.00	2 350.00	2 500.00	2 086.32	3 800.00	2 350.00	2 500.00
Fertilizer	4 605.00	7 838.83	4 240.00	11 312.52	4 405.00	7 585.28	4 100.00	10 429.06
Agrochemical	489.73	4 580.78	1 435.28	4 054.48	502.22	4 497.32	1 452.25	4 042.90
Irrigation	668.00	668.00	668.00	668.00	668.00	668.00	668.00	668.00
Land rental	918.00	898.00	918.00	908.00	788.00	793.00	783.00	818.00
Labour	6 402.00	9 048.00	9 513.32	12 122.00	6 491.40	9 209.08	9 480.32	12 416.00
Harvesting	500.00	6 480.00	2 000.00	5 100.00	563.40	9 000.00	2 837.50	3 960.00
Marketing	0	11 290.13	0	8 984.33	0	10 759.88	0	9 155.06
Total VC	17 271.13	50 003.74	22 174.40	58 999.33	17 304.34	54 062.56	22 794.78	56 251.42
Gross Margin	**23 600.87**	**35 319.26**	**22 456.60**	**12 875.27**	**21 623.66**	**32 016.44**	**22 227.72**	**16 989.08**

Source: Farmer survey (2013).

The gross margins of green maize and butternuts (Table 4.14) were not statistically significantly different (Table 4.15). In winter, Irish Potatoes (Table 4.14) had the highest total variable costs and were the least profitable crop in Makhathini Flats for farmers with less than 5 ha. Table 4.15 shows that the crop gross margins for potatoes is also statistically significantly lower than that of green maize ($p<0.01$). Also looking at the production costs of these two crops, the expenditures per hectare are lower for green maize and higher for Irish potatoes. When capital is a binding constraint, the production of such a crop will influence the crop choice.

Table 4.15: Comparison of mean crop gross margins per hectare in winter for a farmer with a small plot

Crop	*n*	Mean Gross Margins (ZAR)	Std. deviation.	T-test
Green maize	73	23 600.87	11 918.42	***
Cabbages	67	35 319.26	15 374.19	
Green maize	73	23 600.87	11 918.42	n.s.
Butternuts	54	22 456.60	12 784.19	
Green maize	73	23 600.87	11 918.42	***
Irish potatoes	47	12 875.27	8 013.90	

Source: Farmer survey (2013).

Note: ***: Statistically significant at 1% confidence level.
n.s: = not statistically significantly different

The winter crop gross margin budgets presented in Table 4.14 for farmers with large plots shows that green maize is competitive to all other crops grown except cabbages. The cabbage enterprise has highest gross margins in winter for farmers with large plots. There is a statistically significant difference between these gross margins of cabbage and green maize ($p<0.01$) (Table 4.16). Cabbage's competitiveness over green maize is similar to the results obtained for farmers with small plots.

Table 4.16 shows that there was no statistically significant difference between green maize and butternuts gross margins in winter for large plot holder farmers. However, a statistical significant difference was observed between green maize and Irish potatoes ($p<0.05$).

The gross margin budgets presented in Table 4.14 for both small and large plot holder farmers in winter, green maize is competitive to all crops except cabbages. The study looked at winter and summer; therefore gross margin analysis was also carried for both seasons. This was done to see the seasons in which green maize gross margins compete.

4.7.3: Gross margin analysis for crops grown in summer

Table 4.17 presents summer crop budgets for famers with small and large plots. The crop budgets were analysed compared to green maize.

Table 4.16: Comparison of mean crop gross margins per hectare in winter for a farmer with a large plot

Crop	*n*	Mean Gross Margins (ZAR)	Std. deviation.	T-test
Green maize	54	21 623.66	12 749.83	***
Cabbages	66	32 061.44	14 897.07	
Green maize	54	21 623.66	12 749.83	n.s.
Butternuts	69	22 227.72	13 917.28	
Green maize	54	21 623.66	12 749.83	**
Irish potatoes	72	16 989.08	9 043.59	

Source: Farmer survey (2013).

Note: *** and ** statistically significant at 1% and 5% confidence levels respectively.
n.s. = not significantly different

The summer cabbage enterprise for farmers with small plots has the highest gross margin of R41 805.69 ha $^{-1}$. The cabbage enterprise has higher returns than that of green maize (Table 4.18) and the gross margin difference is statistically significant ($p<0.01$).

The summer gross margin for butternuts and Irish potatoes for farmers with small plots, shows that they were not statistically different compared to that of green maize (Table 4.18). Farmers indicated that the reason for poor green maize gross margins in summer is due to low prices due to increased supply of green maize cobs in the market. As a result, the competitiveness of green maize drops significantly in summer.

Green maize and cabbage enterprises gross margins in summer for farmers with large plots shows that the latter has higher gross margins, which are statistically significantly different ($p<0.01$) (Table 4.19). Butternuts and Irish potatoes have higher gross margins than green maize but the difference is not statistically significant (Table 4.19).

4.17: Summer crop gross margin budgets

	Summer gross margin for farmers with small plots (≤5ha)				Summer gross margin for farmers with large plots (>5ha)			
	Green Maize (ZAR)	**Cabbages (ZAR)**	**Butternuts (ZAR)**	**Irish Potatoes (ZAR)**	**Green Maize (ZAR)**	**Cabbages (ZAR)**	**Butternuts (ZAR)**	**Irish Potatoes (ZAR)**
Gross Income	**38 088.00**	**86 292.00**	**39 236.81**	**72 637.42**	**38 664.00**	**85 484.00**	**39 041.60**	**72 200.57**
Seed	1 800.00	9 000.00	1 050.00	17 848.6	1 784.00	9 247.41	1 042.59	16 700.40
Land prep	3 250.00	3 350.00	2 750.00	2 500.00	3 137.40	3 393.10	2 679.82	2 623.00
Fertilizer	5 185.00	7 500.18	3 570.00	12 712.88	4 755.00	7 605.28	4 090.00	13 273.06
Agrochemicals	473.08	6 071.93	1 282.28	3 959.62	485.85	6 622.28	1 180.28	3 965.51
Irrigation	668.00	668.00	668.00	668.00	668.00	668.00	668.00	668.00
Land rental	873.00	893.00	878.00	918.00	818.00	773.00	793.00	783.00
Labour	6 348.00	4 240.00	4 060.59	4 268.00	6 892.80	3 960.00	3 608.12	3 370.00
Harvesting cost	810.74	1 320.00	5 282.00	5 100.00	973.80	1 140.00	5 013.84	5 410.00
Marketing cost	2 432.24	10 786.50	4 904.60	9 079.68	4 791.15	10 685.50	4 880.20	9 025.07
Total VC	23 276.08	44 486.31	24 445.47	57 054.78	24 306.00	44 259.07	23 955.85	55 818.04
Gross Margin	**16 452.94**	**41 805.69**	**14 791.34**	**15 582.64**	**14 358.00**	**41 224.93**	**15 085.75**	**16 382.53**

Source: Farmer survey (2013).

Table 4.18: Comparison of mean crop gross margins per hectare in summer for a farmer with a small plot

Crop	*n*	Mean Gross Margins (ZAR)	Std. deviation.	T-test
Green maize	34	16 452.94	9 317.48	***
Cabbages	71	41 805.69	18 751.36	
Green maize	34	16 452.94	9 317.48	n.s.
Butternuts	31	14 791.34	9 073.82	
Green maize	34	16 452.94	9 317.48	n.s.
Irish potatoes	37	16 989.08	7 859.34	

Source: Farmer survey (2013).

Note: *** Statistically significant at 1% confidence level.
n.s = not significantly different

The increase in the supply of green maize cobs on the market from rain-fed farming in summer lead to price of green maize dropping significantly in summer. This leads to lower green maize gross margins in comparison to winter. Some crops maintain almost the same market price both in winter and summer. This reduces the competitiveness of green maize enterprise in summer for both small and large plot holder farmers in the irrigation scheme.

Table 4.19: Comparison of mean crop gross margins per hectare in summer for a farmer with a large plot.

Crop	*n*	Mean Gross Margins (ZAR)	Std. deviation.	T-test
Green maize	21	14 358.00	8 836.70	***
Cabbages	58	41 224.93	20 397.05	
Green maize	21	14 358.00	8 836.70	n.s.
Butternuts	47	15 085.75	7 091.00	
Green maize	21	14 358.00	8 836.70	n.s.
Irish potatoes	39	16 382.53	9 451.78	

Source: Farmer survey (2013).

Note: *** Statistically significant at 1% confidence level.
n.s. = not significantly different

The competitiveness of sugarcane, an annual crop, was also considered. The annual gross margin of green maize was then compared to the sugarcane. Since most farmers with small plots do not grow sugarcane, only green maize gross margins for farmers with large plots were considered for this comparison. The mean annual gross margin for green maize from both seasons was used. The mean annual gross margins presented in Table 4.20 shows that the difference between green maize and sugarcane was not statistically significant. Sugarcane returns reported in Makhathini are below average as compared to national records and the result is due to low yields. Mazala and Myeni (2009) reported that the poor sugarcane returns for smallholders in South Africa is the result of a combination of factors including management practices, the rapidly increasing cost of production inputs and a low sugar price.

4.20: Annual gross margin for sugarcane and green maize enterprises

Crop	*n*	Mean Gross Margins (ZAR)	Std. deviation.	T-test
Green maize	21	17 990.83	9 417.65	n.s.
Sugarcane	47	19 104.37	12 872.43	

Source: Farmer survey (2013).

Note: n.s. = not significantly different

Key informants indicated that the major setback is the use of ratoon crop, which is poorly managed, with less vigour, pests and disease accumulation fuelled by low input application, continuous monocropping and deteriorating soil health.

4.8: The LP models

The result from the gross budget analysis was used in the formulation of an LP model to test the competitiveness of winter green maize production in Makhathini flats irrigation scheme. Surveys revealed that farmers use part of the income realised from their summer crop enterprises as capital for the winter crop enterprises. Therefore in the LP models, the winter and summer capital constraint is the average amount of capital that farmers indicated to reinvest in cropping activities from their previous season's crop enterprises. This capital constraint was used as the resource limit for all cash costs, which include cost of seed, land preparation, agrochemicals, land rental, irrigation, hired labour, harvesting and marketing. Optimisation is done through the efficient allocation of resources at the farm through an optimal crop enterprise combination. The objective is to describe an optimization model for the two groups of farmers in Makhathini Flats, those managing 5 ha and the second for those owning more than 5 ha of land.

Basing on average crop gross margins for the two groups of farmers, that is large and small plot holders, optimization models that would identify an optimal crop enterprise combination for both winter and summer seasons were developed. This was done to see whether the current crop enterprise combination is optimal and assess the competitiveness of green maize for these two groups of farmers.

The LP models were constructed to reflect the production decisions farmers make under prevailing conditions. However, key informants highlighted that input and output markets change over time and there is a probability that prices used may not apply in the future. Therefore, the study results do not constitute a long term forecast, but rather a short-run view of the crop's competitiveness under current circumstances and assumptions. As indicated in the LP models, farmers indicated the resource limit for each input used. Tables 4.21 and 4.22 shows LP models for the 2012/13 summer and 2013 winter seasons for the different groups of farmers.

The second group of farmers, which are those owning an average of 10.37 ha was also considered for LP model. The LP model developed for this group of farmers included sugarcane. The average land under sugarcane was 5.48 ha, and the balance being allocated to green maize, cabbages, butternuts and Irish potatoes for both summer 2012/13 and winter 2013 seasons.

This section presents the optimal farm plan generated under the assumption that profit maximization is the underlying objective function for farmers in their resource use and allocation decisions. Tables 4.23 and 4.24 presents the results obtained for the summer 2012/13 and winter 2013 seasons for farmers with small and large plots respectively. Comparison is made of results obtained by using LP model and the current cropping plan for the two groups of farmers and the competitiveness of green maize is assessed basing on the land allocated to the crop relative to other crops.

Table 4.21: LP formulation for a farmer with a small plot (<5ha)

Resources	**Crop**				**Resource Limit**
	Green maize	**Cabbages**	**Butternuts**	**Potatoes**	
Summer 2012/13 season					
Land (ha)	1.0	1.0	1.0	1.0	**5ha**
Land rental (ZAR)	873.00	893.00	878.00	918.00	**R2 850.00**
Land prep (ZAR)	3 250.00	3 350.00	2 750.00	2 500.00	**R7 728.80**
Seed (ZAR)	1 800.00	9 000.00	1 050.00	17 848.60	**R15 677.50**
Fertilizer (ZAR)	5 185.00	7 500.18	3 570.00	12 712.88	**R14 669.34**
Agrochemicals (ZAR)	473.08	6 071.93	1 282.28	3 959.62	**R10 011.30**
Irrigation (ZAR)	668.00	668.00	668.00	668.00	**R2 900.00**
Labour (ZAR)	6 348.00	4 240.00	4 060.59	4 268.00	**R25 780.80**
Harvesting (ZAR)	810.74	1 320.00	5 282.00	5 100.00	**R2 976.00**
Marketing (ZAR)	2 432.24	10 786.50	4 904.60	9 079.68	**R18 581.51**
Gross Margin (ZAR)	**16 452.94**	**41 805.69**	**14 791.34**	**15 582.64**	
Capital (ZAR)					**R84 410.97**
	Winter 2013 season				
Land (ha)	1.0	1.0	1.0	1.0	**5ha**
Land rental (ZAR)	918.00	898.00	918.00	908.00	**R3 980.00**
Land prep (ZAR)	1 888.40	2 700.00	2 350.00	2 500.00	**R11 928.80**
Seed (ZAR)	1 800.00	6 500.00	1 050.00	14 400.00	**R5 284.02**
Fertilizer (ZAR)	4 605.00	7 838.83	4 240.00	11 312.52	**R18 929.23**
Agrochemicals (ZAR)	489.73	4 580.78	1 435.28	4 054.48	**R4 971.11**
Irrigation (ZAR)	668.00	668.00	668.00	668.00	**R2 873.00**
Labour (ZAR)	6 402.00	9 048.00	9 513.32	12 122.00	**R35 652.00**
Harvesting (ZAR)	500.00	6 480.00	2 000.00	5 100.00	**R8 930.00**
Marketing (ZAR)	0	11 290.13	0	8 984.33	**R6 537.53**
Gross Margin (ZAR)	23 600.87	35 319.26	22 456.60	12 875.27	
Capital (ZAR)					**R56 510.97**

Source: Farmer survey (2013).

The LP model identifies the most competitive crop enterprises that should enter the model. The LP results show that a farmer with a maximum of 5 ha of land in Makhathini Flats should allocate 0.5 ha and 1.61 ha to green maize and cabbages respectively, in summer. The farmer should allocate 1.2 ha and 3 ha to green maize and butternuts in winter. In order to maximize gross margins from the available resources, butternuts and Irish potatoes should not be grown in summer, whilst cabbages and Irish potatoes should not be grown in winter.

Table 4.22: LP formulation for a farmer with a large plot (>5ha)

Resources	Crop					Resource Limit
	Green maize	Cabbages	Butternuts	Potatoes	Sugarcane	
Summer 2012/13 season						
Land (ha)	1.0	1.0	1.0	1.0	1.0	**10.37ha**
Land rental (ZAR)	818.00	773.00	793.00	783.00	1 000.00	**R2 850.00**
Land prep (ZAR)	3 137.40	3 393.10	2 679.82	2 623.00	0	**R7 728.80**
Seed (ZAR)	1 784.00	9 247.41	1 042.59	16 700.00	0	**R20 187.50**
Fertilizer (ZAR)	4 755.00	7 605.28	4 090.00	13 273.06	1 329.00	**R16 503.23**
Agrochemicals (ZAR)	485.85	6 622.28	1 180.28	3 965.51	575.00	**R14 385.20**
Irrigation (ZAR)	668.00	668.00	668.00	668.00	1 000.00	**R2 900.00**
Labour (ZAR)	6 892.80	3 960.00	3 608.12	3 370.00	330.00	**R25 781.40**
Harvesting (ZAR)	973.80	1 140.00	5 013.84	5 410.00	0	**R2 976.00**
Marketing (ZAR)	4 791.15	10 685.50	4 880.20	9 025.07	0	**R23 907.01**
Gross Margin (ZAR)	**14 358.00**	**41 224.93**	**15 085.75**	**16 382.53**	**0**	
Capital (ZAR)						**R96 410.97**
	Winter 2013 season					
Land (ha)	1.0	1.0	1.0	1.0	1.0	**10.37ha**
Land rental (ZAR)	788.00	793.00	783.00	818.00	1 000.00	**R2 850.00**
Land prep (ZAR)	2 086.32	3 800.00	2 350.00	2 500.00	0	**R7 928.80**
Seed (ZAR)	1 800.00	7 750.00	1 123.71	12 262.40	0	**R12 999.80**
Fertilizer (ZAR)	4 405.00	7 585.28	4 100.00	10 429.06	1 329.00	**R17 401.23**
Agrochemicals (ZAR)	502.22	4 497.32	1 452.25	4 042.90	575.00	**R8 834.20**
Irrigation (ZAR)	668.00	668.00	668.00	668.00	1 000.00	**R2 900.00**
Labour (ZAR)	6 491.40	9 209.08	9 480.32	12 416.00	330.00	**R25 781.40**
Harvesting (ZAR)	563.40	9 000.00	2 837.50	3 960.00	1 500.00	**R6 030.00**
Marketing (ZAR)	0	10 759.88	0	9 155.06	11 615.00	**R31 429.01**
Gross Margin (ZAR)	**21 623.66**	**32 016.44**	**22 227.72**	**16 989.08**	**19 104.37**	
Capital (ZAR)						**R46 510.97**

Source: Farmer survey (2013)

The LP land allocation result shows that winter green maize enterprise is a competitive crop for this group of farmers, being allocated the second biggest land after butternuts. The results show a gross income of R202 349.60 using LP model compared to R198 034.50 using the existing plan. The farmer can increase gross margins by R4 315.10 if LP model recommendations are used and this will result in 2.13 percent increase in total gross margins. Table 4.24 shows the recommended cropping plan using LP model so to maximise farm returns for a farmer with a large plot. The model excludes green maize in summer and includes cabbages in winter. The LP model results shows that the farmer should only grow cabbages in summer and allocate 0.12 ha to green maize, 1.53 ha to cabbages, 0.77 ha to butternuts in winter and 1.28 ha to sugarcane enterprise, which is a perennial crop.

Table 4.23: Existing and optimum cropping plans for a farmer with a small plot in Makhathini Flats irrigation scheme, South Africa, 2013.

CROP	Land area (ha)	
	Existing cropping plan (ha)	**LP results (ha)**
	Summer 2012/13 season	
Green maize	2.04	0.50
Cabbages	1.20	1.61
Butternuts	0.40	0
Irish potatoes	0.61	0
	Winter 2013 season	
Green maize	2.21	1.20
Cabbages	0.80	0
Butternuts	0.53	3.00
Irish potatoes	0.51	0
Gross Margin	**R198 034.50**	**R202 349.60**
Difference in Gross Margin (ZAR)	**R4 315.10**	

Source: LP Model results.

Table 4.24: Existing and optimum cropping plans for a farmer with a large plot in Makhathini Flats irrigation scheme, South Africa, 2013.

CROP	Land Area (ha)	
	Existing cropping plan (ha)	**LP results (ha)**
	Summer 2012/13 season	
Green maize	1.93	0
Cabbages	1.24	2.17
Butternuts	0.41	0
Irish potatoes	0.72	0
Sugarcane	5.48	1.28
	Winter 2013 season	
Green maize	2.40	0.12
Cabbages	0.80	1.52
Butternuts	0.51	0.77
Irish potatoes	0.41	0
Sugarcane	5.48	1.28
Gross Margin	**R297 313.95**	**R336 108.60**
Difference in Gross Margin (ZAR)	**R38 794.65**	

Source: LP Model results.

Green maize enterprise is not competitive for this group of farmers (Table 4.24). The model indicates that green maize enterprise should not be considered in summer, and is allocated the smallest land amongst the competing enterprises in winter. Comparing the LP model result and the existing plan, there is an increase in gross margin by 11.6 percent.

The LP model results shows that green maize production is a competitive crop in Makhathini Flats irrigation scheme for small plot holders both in summer and winter, whilst it is only marginally competitive in winter for large plot holders. It can be concluded that the results obtained from using the LP model are superior to the current cropping plan. The land allocation criterion from LP model yields more income than using the existing plan. Had the farmers used the LP solution, more income would have been realised from the same piece of land and resources. This supports the results of Majeke and Majeke (2010) that LP model results are superior to traditional gross margin budgeting and provide the farmer with an opportunity to realise more income from farm resources.

4.8.1: Shadow prices of excluded crops

Table 4.25 indicates the amount by which farm gross income would be reduced if any of the crops appearing in the table are forced into the programme. The higher the shadow price of an excluded crop, the lower is its chance of being included in the final plan. Shadow prices are marginal returns to investments of available resources. In a maximization problem, they are income penalties; indicating the amount by which farm income would be reduced if any of the excluded activities is forced into the programme (Tanko *et al.,* 2011).

In the study area, butternuts and potatoes were excluded in summer 2012/13 season whilst cabbages and potatoes were excluded in 2013 winter season for a farmer with a small plot. For a farmer with a large plot, maize, potato, butternuts and sugarcane were excluded in summer 2012/13 season whilst only potatoes were excluded in winter 2013 season. For a farmer with a small plot, in winter cabbages has the highest shadow price of R390 768.53 while butternuts in summer has the lowest shadow price of R1 177.16. However for a farmer with a large plot, potatoes in summer have the highest shadow price of 214 205.48 and sugarcane with the lowest shadow price of R8 628.67 in the same season.

4.8.2: Resource allocation results from LP models

The study results have shown that given the existing level of technology, farm resources were not optimally allocated under the existing cropping plan.

Table 4.25: Shadow prices of excluded crops in Makhathini Flats

Farmer with a small plot		Farmer with a large plot	
Summer 2012/13 season			
Excluded crop(s)	**Value (ZAR)**	**Excluded crop(s)**	**Value (ZAR)**
Butternuts	1 177.16	Butternuts	87 110.66
Irish potatoes	35 091.65	Irish potatoes	214 205.48
		Maize	53 733.65
		Sugarcane	8 628.67
Winter 2013 season			
Irish potatoes	18 567.15	Irish potatoes	64 967.06
Cabbages	390 768.53		

Source: LP Model results

The results suggest the need to improve farm management. An examination of the resource utilization pattern in Tables 4.26 and 4.27 for farmers with small and large plots reveals that only few of the specified resources were fully utilized in arriving at the optimal solution. For a farmer with a small plot, resources fully utilised are fertiliser and agrochemicals for the summer season and labour for planting and weeding for winter season. All other resources did not constrain the attainment of the objective function. The shadow prices for fully utilized resources in summer are R0.81 and R10.20 for fertiliser and agrochemicals respectively and R482.91 and R281.79 for planting and weeding labour respectively in winter. Comparing the shadow price of labour with its acquisition price of R60/unit in Makhathini, the shadow price exceeds the acquisition price, implying that the resource's marginal value exceeds marginal cost, thus the farmer still has the incentive to employ more labour. The acquisition cost of fertiliser and agrochemicals in Makhathini exceeds the shadow price for these resources, implying that there is no incentive to increase usage of these two resources.

Table 4.26: Resource allocations and use pattern for a farmer with a small plot

Resource	Use status	Slack (ZAR)	Shadow price - MVP (ZAR)
Summer 2012/13 season			
Land	Not fully utilised	2.88	0
Seed	Not fully utilised	288.37	0
Fertiliser	Fully utilised	0	0.81
Money for land preparation	Not fully utilised	709.03	0
Agrochemicals	Fully utilised	0	10.20
Money for irrigation	Not fully utilised	1 490.25	0
Money for land rental	Not fully utilised	975.43	0
Labour for land preparation	Not fully utilised	41.51	0
Labour for planting	Not fully utilised	54.55	0
Labour for weeding	Not fully utilised	4.92	0
Labour for fertiliser application, irrigation, pest and disease control	Not fully utilised	38.27	0
Labour for harvesting	Not fully utilised	33.26	0
Harvesting material	Not fully utilised	445.22	0
Money for marketing	Not fully utilised	0.01	0
Capital	Not fully utilised	1 145.40	0
Winter 2013 season			
Land	Not fully utilised	0.82	0
Seed	Not fully utilised	0.99	0
Fertiliser	Not fully utilised	788.69	0
Money for land preparation	Not fully utilised	2 670.31	0
Agrochemicals	Not fully utilised	111.90	0
Money for irrigation	Not fully utilised	83.94	0
Money for Land rental	Not fully utilised	147.13	0
Labour for land preparation	Not fully utilised	5.66	0
Labour for planting	Fully utilised	0	482.91
Labour for weeding	Fully utilised	0	281.78
Labour for fertiliser application, irrigation, pest and disease control	Not fully utilised	24.43	0
Labour for harvesting	Not fully utilised	3.35	0
Money for harvesting material	Not fully utilised	2 377.57	0
Money for Marketing	Not fully utilised	6 537.53	0
Capital	Not fully utilised	320 921.91	0

Source: LP Model results

Labour for weeding was fully utilised in summer season for a farmer with a large plot. This shows that labour is a constraint in smallholder farming during peak labour demands for operations like weeding and harvesting. The shadow price for the fully utilised labour in summer is R1 568.85, which exceeds the acquisition price in Makhathini. This implies that the farmer has an incentive to employ additional labour. In winter, fertiliser, agrochemicals, money for irrigation and marketing was fully utilised. The shadow prices for these resources are R3.37, R4.26, R1.38 and R2.83, respectively. The acquisition prices of these resources are higher than their shadow prices, implying that there is an incentive to reduce employment of these resources.

Table 4.27: Resource allocation and use pattern for a farmer with a large plot

Resource	Use status	Slack (ZAR)	Shadow price - MVP (ZAR)
Summer 2012/13 season			
Land	Not fully utilised	8.20	0
Seed	Not fully utilised	121.68	0
Fertiliser	Not fully utilised	0.65	0
Money for land preparation	Not fully utilised	366.16	0
Agrochemicals	Not fully utilised	15.61	0
Money for irrigation	Not fully utilised	1 450.52	0
Money for land rental	Not fully utilised	1 172.68	0
Labour for land preparation	Not fully utilised	41.79	0
Labour for planting	Not fully utilised	49.55	0
Labour for weeding	Fully utilised	0	1 568.85
Labour for fertiliser application, irrigation, pest and disease control	Not fully utilised	37.00	0
Labour for harvesting	Not fully utilised	27.72	0
Harvesting material	Not fully utilised	502.33	0
Money for marketing	Not fully utilised	720.70	0
Capital	Not fully utilised	373.86	0
Winter 2013 season			
Land	Not fully utilised	6.67	0
Seed	Not fully utilised	0.02	0
Fertiliser	Not fully utilised	0	3.37
Money for land preparation	Not fully utilised	30.11	0
Agrochemicals	Fully utilised	0	4.26
Money for irrigation	Fully utilised	0	1.38
Money for land rental	Not fully utilised	147.13	0
Labour for land preparation	Not fully utilised	37.36	0
Labour for planting	Fully utilised	41.64	482.91
Labour for weeding	Fully utilised	41.71	281.78
Labour for fertiliser application, irrigation, pest and disease control	Not fully utilised	0.48	0
Labour for harvesting	Not fully utilised	0.01	0
Harvesting material	Not fully utilised	474.50	0
Money for marketing	Fully utilised	0	2.83
Capital	Not fully utilised	448 764.31	0

Source: LP Model results

In the study area, labour was a constraint for both groups of farmers. This is a result of small family sizes with limited family labour supply for farm activities and capital constraints to use hired labour. Regardless of the evidences of agricultural land challenges for female farmers both in terms of ownership and size in study area (Tables 4.3 and 4.10), land is not constraining factor to households' agricultural (crop) production in the study area.

4.8.3: Sensitivity analysis

Sensitivity analysis was done to investigate the effect of changes in prices of crop inputs and output on the farm gross margins and enterprise combinations respectively. As has been established by researchers in the past, land and labour are important variables in such analysis (Tanko, 2004). The analysis was carried for both groups of farmers for winter and summer seasons.

Table 4.28: Price sensitivity analysis for crops and inputs for farmers with small plots

	Price/Unit	Allowable increase (%)	Allowable decrease (%)
Summer 2012/13 season			
Input prices (right hand side ranges)			
Land	R2 000/ha/year	N/A	57.8
Irrigation	R2 000/ha/year	N/A	51.4
Labour for land preparation	R60/day	N/A	56.2
Labour for planting	R60/day	N/A	58.3
Labour for weeding	R60/day	N/A	5.20
Labour for fertiliser application, pest and disease control	R60/day	N/A	43.5
Labour for harvesting	R60/day	N/A	41.8
Winter 2013 season			
Input prices (right hand side ranges)			
Land	R2 000/ha/year	N/A	16.0
Irrigation	R2 000/ha/year	N/A	2.9
Labour for land preparation	R60/day	N/A	7.6
Labour for planting	R60/day	1.3	0.1
Labour for weeding	R60/day	0.1	4.9
Labour for fertiliser application, pest and disease control	R60/day	N/A	26.2
Labour for harvesting	R60/day	N/A	1.9

Source: LP Model results

Output prices for crops grown in both winter and summer by farmers with small plots were not sensitive to any price changes. This implies that increasing or decreasing the prices of output does not affect the crop enterprise combinations. For inputs used in summer, the model was most sensitive to a decrease in the cost of labour for weeding while it is least sensitive to a decreasing in the cost of land under cultivation. Table 4.28 shows that the cost of land can be reduced by 57.8 percent without changing the optimum farm gross margin. However, a 5.2 percent decrease in the cost of labour for weeding would change the current optimum gross margins. A different trend was observed in winter for the same group of farmers growing the same crops. Increasing the cost of labour for planting by 1.3 percent or decreasing it by 0.1 percent will lead to changes in the optimum farm gross margin. An increase in the cost of weeding labour was also very sensitive, with a 0.1 percent increase leading to changes in current optimum farm gross margin. However, a decrease in the cost of labour for the same operation was only sensitive after a 4.9 percent decrease in the cost of labour. The result shows that reduction in labour wage can increase the gross margin, implying that farmers would increase their gross margin if there is a decrease in the cost of labour. Alternatively, any technology that will reduce cost of labour is bound to increase gross returns in the area.

Table 4.29 shows sensitivity analysis results for farmers with a large plot. The analysis shows that for the summer season, output prices were neither sensitive to price increase nor price decrease. Land in winter was the least sensitive to a decrease in cost. However, the cost of irrigation was very sensitive to both an increase and a decrease of the input in winter. An increase or decrease in the cost of irrigation by 0.1 percent can change the current optimum farm gross margin. Harvesting was also very sensitive to a decrease in the cost of labour in winter. Table 4.29 shows that a slight decrease of 0.1 percent in the cost of harvesting labour will change the optimum gross margins. The cost of labour for fertiliser application, pest and diseases was also sensitive to a decrease in price of the input in winter, indicating that a 0.4 percent decrease will change the current optimum gross margins.

Although increasing the cost of weeding labour by 0.1 percent would change the current optimum gross margins, decreasing the cost of weeding labour was less sensitive to price changes. Optimum gross margins will only change after decreasing the cost of weeding labour by 99.5 percent. This implies that a saturation point has been reached and it is advisable not to employ more labour or apply more inputs, continued application of the input when what is required have been achieved will increase variable cost and as such even depress gross margin. This is the case with inputs which are less sensitive to a price changes. There is therefore some form of enlightenment programme necessary for farmers to efficiently use inputs available to them to achieve increased gross margin in the area.

Table 4.29: Price sensitivity analysis for crops and inputs for farmers with large plots

	Price/Unit	Allowable increase (%)	Allowable decrease (%)
Summer 2012/13 season			
Input prices (right hand side ranges)			
Land	R2 000/ha/year	N/A	79.1
Irrigation	R2 000/ha/year	N/A	50.0
Labour land preparation	R60/day	N/A	56.6
Labour planting	R60/day	N/A	53.0
Labour weeding	R60/day	0.1	99.5
Labour fertiliser application, pest and disease control	R60/day	N/A	42.0
Labour harvesting	R60/day	N/A	34.7
Winter 2013 season			
Input prices (right hand side ranges)			
Land	R2 000/ha/year	N/A	64.3
Irrigation	R2 000/ha/year	0.1	0.1
Labour land preparation	R60/day	N/A	50.1
Labour planting	R60/day	N/A	44.5
Labour weeding	R60/day	N/A	27.7
Labour fertiliser application, pest and disease control	R60/day	N/A	0.4
Labour harvesting	R60/day	N/A	0.1

Source: LP Model results

4.9: Multiple goals in smallholder farming

Although farmers are not producing at the optimum point to maximise farm profits, farmers indicated that they also produce for subsistence, which is common for smallholder farming. Adejobi *et al.* (2003) and Tanko, (2004) argued that the accumulation of monetary income or economic considerations are not the only factors that smallholder farmers takes into account before including certain enterprises in their crop mix. For instance, the production objective to maximise farm gross margins and to produce food for family consumption may be the primary concern of the smallholder farmer while planning farming activities and crop enterprises. More often than not, these goals are conflicting. Farmers further revealed that they grow certain crops not based on their economic competitiveness, but their importance to household food security. This point to a possible shortcoming in the LP model as a tool to increase farm gross margins for smallholder farmers with multiple goals.

CHAPTER 5: CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1: Introduction

The study's general objective was to evaluate the economic competitiveness of green maize production in Makhathini flats irrigation scheme. First, the study focused on understanding the production systems. Secondly, it looked at the effects of household level characteristics on the decision to grow green maize and the proportion of land allocated to the crop. After that, the study then sought to understand and determine the economic performance of green maize production compared to alternative crops grown in Makhathini flats irrigation scheme. Since the crop is becoming a cash crop, the study sought to determine its economic competitiveness under smallholder irrigation, making it different from many other studies carried out in irrigation schemes that looked at production systems without assessing its economic competitiveness and other crops grown.

Using a random sample of 150 irrigators, collected data was analysed using both descriptive and econometric techniques. Descriptive analysis made use of comparisons of means and analysis of goodness of fit. Econometric and mathematical analysis used the two-step Heckman regression model, gross margin analysis and the maximisation linear programming model, respectively. Data from qualitative sources (key informant interviews) were used to contextually interpret the quantitative results. This chapter presents the main conclusions of this study. Based on the empirical results, the chapter also draws several policy recommendations. Furthermore, the last section of this chapter presents the remaining knowledge gaps and suggests areas of further investigation in the future.

5.2: Conclusions

This study found that green maize is grown in both seasons, although more land is allocated to it to in winter. However, there is no significant difference in mean area put under green maize in winter and summer, but more farmers grow green maize in winter than in summer.

The empirical results of the two-step Heckman regression model indicated that age, household size, plot size, access to extension and green maize gross margins are positive significant determinants of growing green maize. A combination of positive and negative factors significantly determines the proportion of land allocated to green maize. The factors with positive effects are gender, marital status, access to credit and green maize gross margins, while those with negative effects are plot size and cabbages gross margins. Therefore, the study concluded that a unit increase or decrease in these variables is responsible for increasing or decreasing the chance to grow green maize and the land allocated to the crop, respectively, ceteris paribus.

The gross margin budgets reveal that green maize was not the highest paying crop, but cabbage has the highest gross margins per hectare in both summer and winter seasons. However, the LP model results indicated that farmers with small plots should not grow cabbages in winter because it is not competitive and has a shadow price of R390 768.53 if forced into the cropping plan, whilst green maize enterprise should not be considered in summer by large plot holders. Sugarcane and potatoes were receiving government support. Although potato production was being supported, farmers reduced the area allocated to potatoes and other crops, and increase their area allocated to cabbages and green maize, especially in winter. However, considering the monoculture nature of the sugarcane crop, farmers cannot substitute their area under sugarcane for green maize in the short run. Despite the fact that farmers can plant a third green maize crop in a year, especially using short season varieties, sugarcane farmers cannot shift from it to green maize or seasonal crops. This indicates the need for a holistic package of complimentary production strategies, where sugarcane yields and quality can be improved to increase profits. This is because yields obtained by farmers in Makhathini flats irrigation scheme are below average potential yields for the region.

This study has also demonstrated a way of enhancing the effectiveness of farm decision-making, choosing farm enterprise combination using the of LP model, which determines how farm resources should be allocated to each enterprise in order to maximise farm profits. The LP model results showed that under the set of constraints, farm resources were not optimally allocated. It determined a profit maximising combination of farm enterprises that are feasible given a set of farm constraints. It also indicated the income that would be lost if excluded enterprises are forced into the cropping plan. The land allocation criteria obtained using the LP yields more income than using the existing plan

This study reveals the importance of access to support services (such as extension, credit, agricultural training, and market support) in producing profitably. Farmers indicated loosing large amounts of produce because of poor markets. Lack of credit and poor marketing systems negatively influenced the profitability of crops, especially sugarcane, butternuts and potatoes. Despite their significant role in promoting increased production and ensuring profitable agricultural production, few farmers received these services. The implication is that crops like sugarcane, with high establishment cost, will be grown by few farmers, while crops like butternuts and potatoes might end up being grown only for family consumption leading to few supplies in the market. Therefore, the study concluded that there is a need for increased government and private sector provision of such services. Training farmers on farm produce marketing would improve their negotiation skills.

To sum up, green maize production is a competitive crop, and thus should continue to be grown as it has better gross margins as compared to other crops and serves a food safety net during the dry winter season. There is also need to ensure other commercial crops like sugarcane, potatoes and butternuts are produced profitably through provision of agricultural credit, reliable markets and other support services. After years of government investment in the sugarcane crop in Makhathini, the enterprise cannot be abandoned and there might need to review the challenges facing farmers in its production. In light of the empirical results and research conclusions, the following section provides specific recommendations to policy makers.

5.3: Policy recommendations

An effective policy plan should include development of efficient distribution and marketing of inputs (such as fertilizers, seeds, etc.), an easy access to credit, agricultural marketing training programs and policies that promote a sustainable and stable market for cash crops.

- Since agricultural production has been credit-driven for decades in South Africa, the provision of credit enables profitable production of sugarcane, butternuts, potatoes and other cash crops in Makhathini flats irrigation scheme. Historically, the South African government provided buffer services for key crops through the operation of a floor price (Greenberg, 2012); this can increase agricultural production and maximum utilization of land resources.

- Looking at farm produce marketing challenges in Makhathini, integration of smallholder farmers into value chains desirable. They can make use of farm association to deliver fresh farm produce to supermarkets without intermediaries. These new opportunities have emerged from the expansion of supermarkets into more distant rural areas, previously only served by informal markets, and government black economic empowerment (BEE) procurement policies have added to the logic and these might be strengthened in Makhathini. For example, the case of Fort Hare Farmers Group of Zanyokwe irrigation scheme which penetrated big markets which include Pick ‘n Pay and Fresh Produce Market in East London as indicated by David *et al.* (2005), can also be adopted in Makhathini.

- Policy makers should also ensure women's ownership of production resources, mainly land, backed by government support to easy agricultural information. Land ownership and credit access in Makhathini was biased towards male farmers, which hampers women farmers to reach their full agricultural production potential. Women are more dominant in the irrigation scheme but are farming on hired land. In addition, the voice of women farmers remains marginalised in both farmer organisations and policymaking.

- Although farmer organisations operate in Makhathini flats irrigation scheme, their effectiveness is limited as farmers face poor access to profitable local markets and financial services, compounded by heavy reliance on farming equipment provided by the government. Strengthening such farmers' organisations is. It is recommended that farmer associations be promoted in the scheme, particularly at block level. The running of these associations should be farmer-led and driven, with outsiders only involved at coordination level and offering technical support.

5.4: Areas of further study

The single difference method of assessing green maize competitiveness in Makhathini flats based on cross section data adopted in this study can be strengthened by using panel data. It is, therefore, recommended that data be collected for several seasons and more robust methods such as difference-in-difference methods that use panel data be employed to evaluate the economic competitiveness of green maize production.

The green maize marketing system is also another area that needs be looked. The price of green maize usually increases significantly as supply dwindles following the start of planting season. De Long (2005) noted that although the green maize market has been opportunistic, the green maize selling price can be two to three times higher than dry maize. This shows that the crop has the potential to bring in good returns for farmers. There might be a need for staggering planting to ensure a constant supply of green maize to the market and assess how this will impact the green maize marketing system.

Green maize value chain is another area with a knowledge gap. For green maize to contribute significantly to farmers' income as a commercial crop, the performance of the value chain needs to be improved. The crop has achieved success as one of the important commercial cash crops in many developed countries as sweet corn. An organizational and institutional analysis of the governance and coordination of these chains could provide policy and other solutions to improve benefits to farmers, without penalizing other actors. Chains work more effectively and efficiently through participatory approaches, such as learning alliances.

Considering the demand for the crop, there might be need to look at the possibilities of breeding maize varieties specifically for green maize production. This is because the current varieties used were bred for yield, diseases resistance, crop stand ability, prolific and other crop production attributes without factoring in the traits of an ideal green maize variety. Qwabe *et al.* (2013) reported that more income can be generated if desired traits for the consumers can be incorporated in hybrids to enable farmers to obtain a premium on green maize sales. She added that the desired traits are a combination of sweet taste, long shelf life, large ears and good roasting ability. Farmers specifically desire a variety that does not dry quickly. Therefore, future studies should aim to improve both the genetics and production economics.

According to the study, agriculture is the main economic activity in the area and employs a significant part of the population. Tools used in this study aimed at farmers' utility optimization but the results highlighted that farmers' decisions are oriented towards the socio-economic objectives. Therefore, it is worth formulating a multi-criteria decision-making model that allocates farm resources efficiently, by optimising a set of important socio-economic objectives. This multi-objective programming model should depict the feasible and efficient resource allocation, as well as indicate trade-offs between economic and social objectives.

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APPENDICES

Appendix A: Questionnaire used for data collection

University of KwaZulu-Natal

An analysis of the economic competitiveness of green maize production in smallholder irrigation schemes: A case of Makhathini Flats Irrigation Scheme in KwaZulu-Natal, a Province of South Africa.

All the information provided here will be treated as **STRICTLY CONFIDENTIAL**

Date of Survey …………………………………………………………………
Name of Enumerator ……………………………………………………………..
Name of Farmer ………………………………………………………………….

1. Household demographics

1.1 What is the total number of your household members? Please complete table below (*Record household head*details in the first row*).

Household member	Relationship to household head	Age	Gender	Marital status	Education level	Main occupation	Availability in the household for family labour (*Days per week*)

Key

Relation to household head	**Gender**	**Marital status**	**Education level**	**Main occupation**
1=Household head* 2=Spouse 3=Daughter /son 4=Other (specify e.g., cousin)	1=Male 0=Female	1=Single 2=Married 3=Divorced 4=Widowed	1 = Not Attended formal education 2= Primary school 3=Secondary school 4=Tertiary school	1=Fulltime farmer 2=Regular salaried job 3=Temporary job 4=Unemployed 5=Self-employed 6=Student 7=Retired 8=Aged/permanently sick 9=Infant(under age) 10=Other (specify)

* *Household head refers to the household head that stays in the household for 4 or more days per week.*

2. Farm Information

2.1: What is the total number of plots you have, their sizes and the type of ownership? Please answer these questions by completing the table below

Plot	Size of plot (ha)	Type of ownership	Land fees per year (ZAR) *(where applicable)*
1			
2			
3			
4			
5			

Key

Type of ownership
1 = Owning; 2 = Renting from another farmer

2.2: Do you own the following assets? *(Indicates number owned in the appropriate box below, zero if not owned).*

Farm assets	Yes = 1; No = 0	Number owned	Value of each asset (ZAR)
Tractor			
Plough			
Harrows			
Knapsack Sprayer			
Wheelbarrow			
Vehicle			
Motorbike			
Bicycle			
Other(Specify)			
Total value of assets			

2.3: Do you own the following livestock? *(Indicates number owned in the appropriate box below, zero if not owned).*

Livestock Type	Yes = 1; No = 0	Number currently owned
Cattle		
Goats		
Sheep		
Pigs		
Chickens		
Other(Specify)		

3.1: Agricultural Extension Services in Makhathini Flats Irrigation Scheme

Do you receive agricultural extension services?	Yes = 1; No = 0
If yes, on average how many times per month do you meet the agricultural extension officer?	
Is there any crop(s) that agricultural extension officers advocate for?	Yes = 1; No = 0
If yes, name these crops?	

4.1: Labour Supply

Do you have enough family labour for your farm activities?	Yes = 1; No = 0
If No, answer the following questions?	
If you lack family labour, which crop(s) do you usually hire labour for? *(List name of the crop(s))*	During what operations do you normally lack labour for the crop mentioned?

Key

Farm operations 1 = Land preparation; 2 = Planting; 3 = Weeding; 4 = Spraying and Irrigation; 5 = Harvesting

4.2: Catering for short labour supply

If you experience shortage of family labour, how do you deal with the shortage?	1 = Hired labour; 3 = Other (specify) 2 = Family arrangements;

5.1: Green maize production

Do you grow green maize?	Yes = 1; No = 0
If Yes to the above question, in which seasons do grow green maize?	1 = Winter; 2 = Summer; 3 = Both

5.2: Area under green maize production in summer and winter

If you grow green maize in both seasons, please answer the following questions	
Area allocated in Summer 2012/13 (ha)	**Area allocated in Winter 2013 (ha)**

6.1: Green Maize Production in winter 2013 and summer 2012/13 season

If yes to question 5.2 above, please answer the questions below for green maize production			
Summer 2012/13 season			
Rain-fed/Irrigated	**Type of seed used**	**Amount (Kg)**	**Cost of seed (ZAR)**
Winter 2013 season			

Key

Rain-fed or Irrigated 1 = Rain-fed; 2 = Irrigated	**Type of seed** 1 = Retained seed; 2 = Hybrid seed

6.2: Fertiliser application for green maize

For the area allocated to green maize above, do you apply fertilizer?		Yes = 1; No = 0
If yes to question above, please answer the sections below for green maize production		
Summer 2012/13 season		
Type of Fertiliser	**Amount Used (Bags)**	**Cost of Fertiliser/bag (ZAR)**
Basal dressing		
Top dressing		
Winter 2013 season		
Basal dressing		
Top dressing		

6.3: Chemical application for 2013 green maize

For the area under green maize above, do you apply chemicals?		Yes = 1; No = 0
If yes to question above, please answer the sections below for green maize production		
Pesticide	**Summer 2012/13 season**	**Winter 2013 season**
Name of pesticide		
Amount used (Kg; Litres; Ml)		
Cost of quantity used (ZAR)		
Herbicides		
Name of herbicide		
Amount used (Kg; Litres; Ml)		
Cost of quantity used (ZAR)		

6.4: Cost of operations for 2013 winter green maize

For the area under winter green maize above, how do you carry out the following farm operations and their cost?				
	Summer 2012/13 season		**Winter 2013 season**	
Operation	**Mechanically**	**Manually**	**Mechanically**	**Manually**
Land preparation				
Planting				
Weeding				
Fertiliser application				
Pest Control				
Irrigation				
Harvesting				
Other(Specify)				

6.5: If you are using manual labour, what is the cost of the following operations for winter green maize?

For the area under green maize above, what do you use for the following farm operations and their cost?					
Operations	**Family Labour**		**Hired Labour**		
	No. of people	**Days spend**	**No. of people hired**	**Days spend**	**Cost of hired labour per stated operation (ZAR)**
Land preparation					
Planting					
Weeding					
Fertiliser application					
Pest control					
Irrigation					
Harvesting					
Other(Specify)					

6.6: If you are using manual labour, what is the cost of the following operations for summer green maize?

For the area under green maize above, what do you use for the following farm operations and their cost?					
Operations	**Family Labour**		**Hired Labour**		
	No. of people	**Days spend**	**No. of people hired**	**Days spend**	**Cost of hired labour per stated operation (ZAR)**
Land preparation					
Planting					
Weeding					
Fertiliser application					
Pest control					
Irrigation					
Harvesting					
Other(Specify)					

7.1: Green maize marketing

Who determines the green maize price?		Farmer = 1; Hawkers/Buyers = 0	
What is the price per cob (R/Cob) for the below mentioned picks? Answer the following questions			
Winter 2013 season		**Summer 2012/2013 season**	
1st pick	**2nd pick**	**1st pick**	**2nd pick**
(ZAR)	(ZAR)	(ZAR)	(ZAR)

7.2: Expected green maize price/cob

Are you satisfied with the price per cob in summer 2012/13 and winter 2013 season?			Yes = 1; No = 0
If No to question above, how much do you expect for the below mentioned picks?			
Summer 2012/2013 season		**Winter 2013 season**	
1st pick	**2nd pick**	**1st pick**	**2nd pick**
(ZAR)	(ZAR)	(ZAR)	(ZAR)

7.3: Markets for green maize

Where do you sell your green maize and the cost of transporting to the market for the seasons stated?			
Green Maize Markets		**Cost of transportation:** 0 *(zero) if its farm gate.* (ZAR)	
Summer 2012/13	**Winter 2013**	**Summer 2012/13**	**Winter 2013**

Key

Market outlet
1 = Farm gate; 2 Contractors; 3 = Shops in town; 4 = Others (specify) ………………………..

7.4: Unsold green maize

What do you do with unsold green maize? Family consumption = 1; Sell as grain = 0	
If you sell, how many 50kg bags do you sell?	
How much do you sell per bag?	(ZAR)…………
If you consume, how much do you think you consume if converted to grain in bags?	

8.1: Crop Production in Makhathini Flats Irrigation Scheme

Do you grow any other crops except green maize?			Yes = 1; No = 0
If yes to question above, please answer the questions below?			
Summer 2012/13 season			
Crops grown	**Type of seed used**	**Rain-fed/Irrigated**	**Area allocated (ha)**
Winter 2013 season			

Key

Type of seed used	**Rain-fed/Irrigated**
1 = Retained seed; 2 = Hybrid seed	1 = Rain-fed; 2 = Irrigated

8.2: Chemicals used for other crops grown

For the other crops grown mentioned above, do you apply chemicals?			Yes = 1; No = 0
If yes to question above, please answer the questions below?			
Summer 2012/13 season			
Major crops	**Pesticide**	**Amount used**	**Cost of pesticide used (ZAR)**
	Herbicide	**Amount used**	**Cost of herbicide used (ZAR)**
Winter 2013 season			
Major crops	**Pesticide**	**Amount used**	**Cost of pesticide used (ZAR)**
	Herbicide	**Amount used**	**Cost of herbicide used (ZAR)**

8.3: Fertilizers used for crops grown

For the major crops grown in indicated above, do you apply fertilizer?			Yes = 1; No = 0
If yes to question above, please answer the questions below?			
Summer 2012/13 season			
Major crops grown	**Type of fertiliser**	**Amount used (Bags)**	**Cost of fertiliser/bag (ZAR)**
Major crops grown	**Winter 2013 season**		
	Type of fertiliser	**Amount used (Bags)**	**Cost of fertiliser/bag (ZAR)**

Key

Type of Fertiliser
1 = Basal dressing; 2 = Top dressing

8.4: Agronomic Practices/operations for other crops grown

How do you carry out the following agronomic practices for each mentioned crop?										
Crop	**Land Preparation**		**Planting**		**Wedding**					
	Hand hoeing	Mechanically /Chemically	Hand hoeing	Mechanically	Hand hoeing	How many times	Mechanically /Chemically	How many times	Herbicide application	How many applications
Summer 2012/13 season										
Winter 2013 season										

8.5: Labour requirements for land preparation, planting and weeding for crops grown

Crop	Land Preparation				Planting				Weeding			
	Family labour		Hired labour		Family labour		Hired labour		Family labour		Hired labour	
	No. of people	Days spend	No. of people	Days spend	No. of people	Days spend	No. of people	Days spend	No. of people	Days spend	No. of people	Days spend
Summer 2012/13 season												
Winter 2013 season												

8.6: Labour requirements for irrigation, pest and disease control and harvesting for crops grown

Crop	Irrigation				Pest and disease Control				Harvesting			
	Family labour		Hired Labour		Family labour		Hired Labour		Family labour		Hired Labour	
	No. of people	Days spend	No. of people	No. of days	No. of people	Days spend	No. of people	No. of days	No. of people	Days spend	No. of people	No. of days
Summer 2012/13 season												
Winter 2013 season												

8.7: Cost of hired labour for each operation for the crops grown

Crop	Cost of hired labour per each operation per day (ZAR)					
	Land preparation	Planting	Weeding	Irrigation	Pest and disease control	Harvesting
Summer 2012/13 season						
Winter 2013 season						

9.1: Markets for crops grown in Makhathini

Where do you sell your farm produce?		
Crop produce	**Market outlet**	**Cost of transportation:** 0 *(zero) if its farm gate.* **(ZAR)**
Summer 2012/13 season		
Winter 2013 season		

Key

Market outlet
1 = Farm gate; 2 = Contractors; 3 = Shops in town;
4 = Others (specify) ………………………

9.2: Selling price for the major crops grown

What is the selling price/unit of the major crops grown listed above?			
Crop produce	**Unit used**	**Selling price/unit (ZAR)**	**Quantity harvested per area mentioned above**
Summer 2012/13 season			
Winter 2013 season			

Key

Units used
1 = Kg; 2 = Bags; 3 = Heads; 4 = Box

9.3: Market challenges

Do you sometimes fail to sell your crop produce?		Yes = 1; No = 0
If Yes to question above, how often do you fail to sell your crop produce due to lack of market?		
Crop produce	**Summer 2012/13 season**	**Winter 2013 season**

Key

Failing to Sell Farm Produce
1=Never; 2=Sometimes; 3=Always

10.1: Agricultural support services in Makhathini Flats irrigation scheme: Crops receiving support/subsidies

Is there any crop receiving subsidy/support?		Yes = 1; No = 0
If Yes, name the crop, subsidy provider and support being received		
Crop	**Subsidy/Support provider**	**Subsidy/Support received**

Key

Market outlet
1 = Farm gate; 2 = Contractors; 3 = Shops in town 4 = Other (Specify)

10.2: Agricultural support services in Makhathini Flats irrigation scheme: Money spent financing cropping enterprises for seasons specified

How much did you spent on financing your crop enterprises on the past 2012/13 summer season?	(ZAR)…………
How much did you spent on financing your crop enterprises on the past 2013 winter season?	(ZAR)…………
Did you use any agricultural credit or loan facility in the past 2012/13 summer season and the current 2013 winter season?	Yes = 1; No = 0
If yes to question above, what was the source of credit/loan? Input supplier = 1; Output buyer = 2; Financial institution = 3; Government Agricultural Support Schemes = 4; Other = 5 (Specify)………………..	
What was the purpose of the loan/credit? Input purchasing = 1; Labour paying = 2; Other = 3 (specify)……………………………..	
Were you able to pay back the loan/credit in time?	Yes = 1; No = 0
If No to question above, please specify the reason(s) why you failed to pay back the loan/credit …………………..………………………………………………………… ……………………………………………………………………………………	

11.1: Water Access in Makhathini Flats irrigation scheme

Are you a member of the Makhathini Flats irrigation scheme?	Yes = 1; No = 0
If Yes for question above, how long have you been a member of the Makhathini Flats irrigation scheme?	..............years
Which block do you belong to?	Block No......
How many times per week do you have access to water in your plot(s)?	...............days
Have you ever had a shortage of water supply in your block?	Yes = 1; No = 0
If yes in to question above, how severe was the problem? Slightly = 0; Strongly = 1; Severe = 2	
Do you pay any fees for water or water related services?	Yes = 1; No = 0
If yes to question above, how much do you pay? *(State as e.g. Rands/month, Rands/Season; Rands/ha, etc)*	(ZAR)............

11.2: Reliability of Water Supply and State of Irrigation Infrastructure in Makhathini Flats Irrigation Scheme

Rate the extent to which you agree with the following statements pertaining to water supply and Irrigation Infrastructure in Makhathini Flats irrigation scheme (*Tick appropriate box*).					
	Strongly disagree = 0	Disagree = 1	Neutral = 2	Agree = 3	Strongly agree = 4
Reliable water supply to my plot(s)					
Satisfactory irrigation infrastructure maintenance					

12.1: Makhathini Flats Irrigation Scheme management

Is there any farmer association in your block/scheme?	Yes = 1; No = 0
Do you participate in management of the scheme?	Yes = 1; No = 0
How would you rate the overall scheme management? Very poor = 0; Poor = 1; Average = 2; Good = 3; Very good = 4	

13.1: Concluding remarks

Final general comments ....

Siyabonga/Thank you

Appendix B: Key informants discussion guide

1. Which institutional organisation manages the irrigation scheme?
2. What is the plot size allocated to farmers?
3. What are the most commonly crops grown in winter?
4. What are the most commonly crops grown in summer?
5. Are there crops receiving support or subsidies from the government or private companies?
6. If there are crops receiving support or subsidies, how is the support or subsidy given?
7. What are the challenges faced by farmers in the irrigation scheme?
    - Input access?
    - Production?
    - Marketing?
8. What are your suggested solutions to the challenges mentioned above?
9. Are there any challenges faced by farmers which are gender specific? Explain?
10. What are your suggested solutions to the challenges mentioned above?
11. Institutional arrangements regarding access to irrigable land:
    - What are the criteria used on access to land in the irrigation scheme?
    - What criteria used to replace farmers, deceased or those who no longer interested in farming?
    - Are farmers allowed to rent out their land to other farmers outside the scheme?

Appendix C: Variable codes as used in Stata estimations

Variable code	Variable Description
GENDER	Household head gender (1=Male, 0 = Female)
AGE	Household head age in years
EDUC	Household head (years of schooling)
MARITAL_STAT	Household head marital status (1=Married, 0=Non-married)
HSEHOLD_SIZ	Household size in adult equivalents
AREA_WGM	Area (ha) under winter green maize 2013 season
SGM_AREA	Area (ha) under summer green maize 2012/13 season
PLOT_SIZ	Household total land size in hectares (ha)
LIV_UNITS	Livestock size in Tropical Livestock Units (TLUs)
EXTENSION	Access to extension service (1= Yes, 0=No)
CREDIT	Access to credit (1=Yes, 0=No)
ASS_MEMBER	Member of Makhathini Irrigation Scheme: (1 = Yes; 0 = No)
SCHEME_MGT	Participation in scheme management: 1 = Yes; 0 = No
GM_CABB	Gross margin cabbages
GM_GREENMZ	Gross margin green maize
GM_SUGRCN	Gross margin sugarcane
GM_BUTNT	Gross margin butternuts
GM_POT	Gross margin potatoes

Appendix D: Equivalence scales of recommended energy intakes by age categories

Category	Age (Years)	Average energy allowance per day (Kilocalories)	Equivalence
Infants and children	0-0.5	650	0.22
	0.5-1	850	0.29
	1-3	1300	0.45
	4-6	1800	0.62
	7-10	2000	0.69
Males	11-14	2500	0.86
	15-18	3000	1.03
	19-25	2900	1.00
	25-50	2900	1.00
	51+	2300	0.79
Females	11-14	2200	0.76
	15-18	2200	0.76
	19-25	2200	0.76
	25-50	2200	0.76
	51+	1900	0.66

Source: NRS (1989), cited in Wale (2004).

Appendix E: Tropical livestock units (TLU) scales

Animal	Animal
Cattle	1.00
Sheep	0.10
Goats	0.10
Pigs	0.20
Chickens	0.01

Source: Peden *et al.* (2007).

Appendix F: Determinants of growing green maize: Probit Regression Results

```
. probit GRWNG_GM AGE GENDER MARITAL_STAT EDUC HSEHOLD_SIZ PLOT_SIZ OWNRSHP_STAT FARM_ASSETS LIV_UNITS EXT
> ENSION CREDIT ASS_MEMBER SCHEME_MGT GM_CABB GM_GREENMZ, vce(robust)

Iteration 0:   log pseudolikelihood = -73.653059
Iteration 1:   log pseudolikelihood = -50.443036
Iteration 2:   log pseudolikelihood = -47.533528
Iteration 3:   log pseudolikelihood = -47.459292
Iteration 4:   log pseudolikelihood =  -47.45925
Iteration 5:   log pseudolikelihood =  -47.45925

Probit regression                               Number of obs   =        150
                                                Wald chi2(15)   =      55.00
                                                Prob > chi2     =     0.0000
Log pseudolikelihood =  -47.45925               Pseudo R2       =     0.3556
```

GRWNG_GM	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
AGE	.0626454	.0213575	2.93	0.003	.0207854	.1045054
GENDER	.0000816	.3075166	0.00	1.000	-.6026398	.602803
MARITAL_STAT	-.3896719	.339185	-1.15	0.251	-1.054462	.2751185
EDUC	.4583815	.3423289	1.34	0.181	-.2125708	1.129334
HSEHOLD_SIZ	.2929347	.0972856	3.01	0.003	.1022584	.4836109
PLOT_SIZ	.1435427	.0424576	3.38	0.001	.0603274	.2267581
OWNRSHP_STAT	.3641703	.3098467	1.18	0.240	-.243118	.9714587
FARM_ASSETS	-.3511734	.4643164	-0.76	0.449	-1.261217	.55887
LIV_UNITS	.0117591	.0472648	0.25	0.804	-.0808782	.1043964
EXTENSION	.6494537	.3124045	2.08	0.038	.037152	1.261755
CREDIT	.0043945	.3415787	0.01	0.990	-.6650875	.6738765
ASS_MEMBER	-.0696154	.1087839	-0.64	0.522	-.2828279	.1435971
SCHEME_MGT	.4549971	.3378515	1.35	0.178	-.2071796	1.117174
GM_CABB	-.0000128	.0000101	-1.26	0.207	-.0000326	7.07e-06
GM_GREENMZ	.0000264	.0000139	1.89	0.058	-9.24e-07	.0000537
_cons	-4.376085	1.442117	-3.03	0.002	-7.202583	-1.549588

.

Appendix G: Marginal Effects on determinants of growing green maize

```
. margins, dydx(AGE GENDER MARITAL_STAT EDUC HSEHOLD_SIZ PLOT_SIZ OWNRSHP_STAT FARM_ASSETS LIV_UNITS EXTEN
> SION CREDIT ASS_MEMBER SCHEME_MGT GM_CABB GM_GREENMZ)

Average marginal effects                        Number of obs   =        150
Model VCE    : Robust

Expression   : Pr(GRWNG_GM), predict()
dy/dx w.r.t. : AGE GENDER MARITAL_STAT EDUC HSEHOLD_SIZ PLOT_SIZ OWNRSHP_STAT FARM_ASSETS LIV_UNITS
               EXTENSION CREDIT ASS_MEMBER SCHEME_MGT GM_CABB GM_GREENMZ
```

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
AGE	.010875	.0035695	3.05	0.002	.003879	.0178711
GENDER	.0000142	.0533841	0.00	1.000	-.1046167	.104645
MARITAL_STAT	-.0676458	.0591571	-1.14	0.253	-.1835916	.0482999
EDUC	.0795736	.0583138	1.36	0.172	-.0347194	.1938666
HSEHOLD_SIZ	.0508525	.0159668	3.18	0.001	.0195582	.0821469
PLOT_SIZ	.0249186	.0069665	3.58	0.000	.0112644	.0385727
OWNRSHP_STAT	.0632188	.0541519	1.17	0.243	-.042917	.1693546
FARM_ASSETS	-.0609626	.0798983	-0.76	0.445	-.2175604	.0956352
LIV_UNITS	.0020413	.0082159	0.25	0.804	-.0140616	.0181442
EXTENSION	.1127431	.0528851	2.13	0.033	.0090903	.216396
CREDIT	.0007629	.0593087	0.01	0.990	-.11548	.1170058
ASS_MEMBER	-.012085	.0186004	-0.65	0.516	-.0485412	.0243711
SCHEME_MGT	.0789861	.058993	1.34	0.181	-.0366381	.1946103
GM_CABB	-2.22e-06	1.77e-06	-1.25	0.210	-5.69e-06	1.25e-06
GM_GREENMZ	4.58e-06	2.34e-06	1.96	0.050	-3.81e-09	9.16e-06

Appendix H: Determinants of proportion of land allocated to green maize: Tobit Regression Results

```
. tobit WGM_LR AGE GENDER MARITAL_STAT EDUC HSEHOLD_SIZ PLOT_SIZ OWNRSHP_STAT FARM_ASSETS LIV_UNITS EXTENS
> ION CREDIT SCHEME_MGT GM_CABB GM_GREENMZ lambda, ll(0) ul(1) vce(robust)

Tobit regression                                  Number of obs   =        150
                                                  F(  15,    135) =       9.34
                                                  Prob > F        =     0.0000
Log pseudolikelihood = -88.380267                 Pseudo R2       =     0.4020
```

WGM_LR	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
AGE	.0021311	.0041901	0.51	0.612	-.0061556	.0104178
GENDER	.1541284	.0825081	1.87	0.064	-.0090472	.3173039
MARITAL_STAT	.1708233	.0875937	1.95	0.053	-.0024101	.3440568
EDUC	.0638438	.0894172	0.71	0.476	-.1129958	.2406835
HSEHOLD_SIZ	.0410407	.0265954	1.54	0.125	-.0115567	.0936381
PLOT_SIZ	-.0617667	.0112672	-5.48	0.000	-.0840498	-.0394836
OWNRSHP_STAT	.0898565	.0801941	1.12	0.264	-.0687429	.2484558
FARM_ASSETS	-.1118121	.0693069	-1.61	0.109	-.2488798	.0252556
LIV_UNITS	.0121469	.0091668	1.33	0.187	-.0059823	.030276
EXTENSION	.0860509	.0880496	0.98	0.330	-.0880841	.2601859
CREDIT	.150995	.0809156	1.87	0.064	-.0090311	.3110211
SCHEME_MGT	.0064899	.0786648	0.08	0.934	-.1490848	.1620646
GM_CABB	-9.00e-06	3.22e-06	-2.80	0.006	-.0000154	-2.63e-06
GM_GREENMZ	.000019	5.05e-06	3.75	0.000	8.97e-06	.000029
lambda	.033397	.1574129	0.21	0.832	-.2779173	.3447112
_cons	-.1070786	.3392276	-0.32	0.753	-.7779664	.5638092
/sigma	.3805065	.045295			.2909268	.4700861

```
  Obs. summary:         23  left-censored observations at WGM_LR<=0
                        81     uncensored observations
                        46 right-censored observations at WGM_LR>=1

.
```

Appendix I: Marginal Effects of proportion of land allocated to green maize

```
. margins, dydx( AGE GENDER MARITAL_STAT EDUC HSEHOLD_SIZ PLOT_SIZ OWNRSHP_STAT FARM_ASSETS LIV_UNITS EXTE
> NSION CREDIT SCHEME_MGT GM_CABB GM_GREENMZ lambda)

Average marginal effects                          Number of obs   =        150
Model VCE    : Robust

Expression   : Linear prediction, predict()
dy/dx w.r.t. : AGE GENDER MARITAL_STAT EDUC HSEHOLD_SIZ PLOT_SIZ OWNRSHP_STAT FARM_ASSETS LIV_UNITS
               EXTENSION CREDIT SCHEME_MGT GM_CABB GM_GREENMZ lambda
```

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
AGE	.0021311	.0041901	0.51	0.611	-.0060814	.0103435
GENDER	.1541284	.0825081	1.87	0.062	-.0075844	.3158412
MARITAL_STAT	.1708233	.0875937	1.95	0.051	-.0008572	.3425039
EDUC	.0638438	.0894172	0.71	0.475	-.1114106	.2390983
HSEHOLD_SIZ	.0410407	.0265954	1.54	0.123	-.0110852	.0931666
PLOT_SIZ	-.0617667	.0112672	-5.48	0.000	-.08385	-.0396834
OWNRSHP_STAT	.0898565	.0801941	1.12	0.263	-.0673212	.2470341
FARM_ASSETS	-.1118121	.0693069	-1.61	0.107	-.2476511	.0240269
LIV_UNITS	.0121469	.0091668	1.33	0.185	-.0058198	.0301135
EXTENSION	.0860509	.0880496	0.98	0.328	-.0865231	.2586249
CREDIT	.150995	.0809156	1.87	0.062	-.0075966	.3095866
SCHEME_MGT	.0064899	.0786648	0.08	0.934	-.1476902	.16067
GM_CABB	-9.00e-06	3.22e-06	-2.80	0.005	-.0000153	-2.69e-06
GM_GREENMZ	.000019	5.05e-06	3.75	0.000	9.06e-06	.0000289
lambda	.033397	.1574129	0.21	0.832	-.2751266	.3419206

Appendix J: Correlation matrix for variables used in regression analysis

Correlation matrix of coefficients of regress model

e(V)	AGE	GENDER	MARITA~T	EDUC	HSEHOL~Z	PLOT_SIZ	OWNRSH~T	FARM_A~S	LIV_UN~S
AGE	1.0000								
GENDER	0.0131	1.0000							
MARITAL_STAT	-0.1937	0.2401	1.0000						
EDUC	0.0908	-0.0688	-0.1322	1.0000					
HSEHOLD_SIZ	-0.2932	0.0387	0.0342	-0.2274	1.0000				
PLOT_SIZ	-0.0359	-0.1951	-0.2796	0.1089	-0.1390	1.0000			
OWNRSHP_STAT	0.0239	0.0995	0.1201	-0.1680	-0.0113	0.1349	1.0000		
FARM_ASSETS	0.0450	-0.1258	-0.0626	-0.0788	0.1180	0.1365	0.1432	1.0000	
LIV_UNITS	-0.1796	-0.0694	-0.1971	-0.0484	-0.1501	-0.0166	0.1116	0.1297	1.0000
EXTENSION	0.0412	0.0395	0.0229	-0.1158	0.0251	-0.1112	0.0921	0.0421	0.0492
CREDIT	-0.0373	-0.0620	0.0775	-0.0633	0.0155	-0.1471	-0.0004	0.0480	-0.1898
ASS_MEMBER	-0.0786	0.1183	-0.1121	-0.0607	0.0216	0.1472	0.0085	0.0286	0.0974
SCHEME_MGT	-0.0070	0.0884	0.1260	0.0084	0.0120	-0.1062	0.2417	0.0831	-0.0158
GM_CABB	-0.0379	-0.0828	-0.0179	0.2680	-0.0512	0.1348	0.0972	0.1284	-0.0922
GM_GREENMZ	0.0048	-0.0519	-0.0602	-0.0318	-0.1241	0.2284	-0.1093	-0.1215	-0.0716
_cons	-0.5091	-0.1350	-0.1911	-0.3300	0.0782	-0.1535	-0.4551	-0.3361	0.1051

e(V)	EXTENS~N	CREDIT	ASS_ME~R	SCHEME~T	GM_CABB	GM_GRE~Z	_cons
EXTENSION	1.0000						
CREDIT	-0.0426	1.0000					
ASS_MEMBER	0.0299	-0.1652	1.0000				
SCHEME_MGT	0.1281	0.0229	-0.0538	1.0000			
GM_CABB	-0.0017	0.1143	0.0115	0.0560	1.0000		
GM_GREENMZ	0.0385	-0.1200	-0.0653	0.0673	0.1146	1.0000	
_cons	-0.2001	-0.0070	-0.0354	-0.2702	-0.4423	-0.1443	1.0000

.

Appendix K: Variance Inflation Factors for variables used in regression analysis

. estat vif

Variable	VIF	1/VIF
PLOT_SIZ	1.47	0.679947
LIV_UNITS	1.38	0.722919
MARITAL_STAT	1.38	0.724276
AGE	1.37	0.728515
HSEHOLD_SIZ	1.35	0.739122
EDUC	1.30	0.770782
OWNRSHP_STAT	1.30	0.771282
GM_GREENMZ	1.22	0.816508
GM_CABB	1.22	0.822686
FARM_ASSETS	1.19	0.840843
CREDIT	1.17	0.855115
GENDER	1.16	0.860793
SCHEME_MGT	1.14	0.873381
ASS_MEMBER	1.12	0.889307
EXTENSION	1.06	0.943979
Mean VIF	1.26	

.

Appendix L: Linear programming model results for a farmer with a small plot

```
NAME
 CANDIDATE OBJECTIVE ROW(S) IS (ARE):
 GM

 EOF IN MPS FILE; LINES READ=      242

 LP OPTIMUM FOUND AT STEP      5

        OBJECTIVE FUNCTION VALUE

       GM)      202349.6

  VARIABLE        VALUE          REDUCED COST
    MAIZE1         0.500618          0.000000
    CABGS1         1.609779          0.000000
    BTNTS1         0.000000       1177.156372
    POTAT1         0.000000      35091.636719
   MZSELL1         2.993696          0.000000
   CABSEL1        73.921066          0.000000
   BUTSEL1         0.000000          0.000000
   POTSEL1         0.000000          0.000000
    TRANS1         0.000000          0.000000
   GMCOUNT    114007.007812          0.000000
    MAIZE2         1.198699          0.000000
    CABGS2         0.000000     390768.531250
    BTNTS2         2.976539          0.000000
    POTAT2         0.000000      18567.150391
   MZSELL2         7.371998          0.000000
   CABSEL2         0.000000          0.000000
   BUTSEL2        61.078575          0.000000
   POTSEL2         0.000000          0.000000
  GM2COUNT     88342.609375          0.000000


       ROW   SLACK OR SURPLUS     DUAL PRICES
    LAND1)         2.889602          0.000000
  LNDPRP1)       709.030212          0.000000
  LBORLP1)        41.514694          0.000000
  LBORPL1)        54.548611          0.000000
  LBORWD1)         4.935620          0.000000
  LBORFI1)        38.270493          0.000000
  LBORHV1)        33.255527          0.000000
    SEED1)       288.373138          0.000000
  FRTLZR1)         0.000000          0.807819
  AGRCHM1)         0.000000         10.204153
  IRRGTN1)      1490.254517          0.000000
  LNRNTL1)       975.427368          0.000000
  HVSTNG1)       445.220093          0.000000
  MRKTNG1)         0.001500          0.000000
  MZTRNS1)         0.000000       5400.000000
  CBTRNS1)         0.000000       2450.000000
  BTTRNS1)         0.000000       1952.079956
  PTTRNS1)         0.000000       2426.909912
 CAPITAL1)      1145.398560          0.000000
```

GM1)	0.000000	-1.000000
LAND2)	0.824762	0.000000
LNDPRP2)	2670.311035	0.000000
LBORLP2)	5.661527	0.000000
LBORPL2)	0.000000	482.911926
LBORWD2)	0.000000	281.788605
LBORFI2)	24.438202	0.000000
LBORHV2)	3.350841	0.000000
SEED2)	0.996302	0.000000
FRTLZR2)	788.697388	0.000000
AGRCHM2)	111.904739	0.000000
IRRGTN2)	83.941277	0.000000
LNRNTL2)	147.131866	0.000000
HVSTNG2)	2377.573242	0.000000
MRKTNG2)	6537.529785	0.000000
MZTRNS2)	0.000000	5724.709961
CBTRNS2)	0.000000	2150.000000
BTTRNS2)	0.000000	2175.000000
PTTRNS2)	0.000000	2355.000000
CAPITAL2)	320921.906250	0.000000
GM2)	0.000000	-1.000000

NO. ITERATIONS= 5

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
MAIZE1	0.000000	38005.847656	2726.789307
CABGS1	0.000000	47700.656250	6630.125488
BTNTS1	0.000000	1177.156738	INFINITY
POTAT1	0.000000	35091.636719	INFINITY
MZSELL1	0.000000	6355.492676	455.984894
CABSEL1	0.000000	1038.777344	144.384262
BUTSEL1	0.000000	58.565010	INFINITY
POTSEL1	0.000000	1172.456909	INFINITY
TRANS1	0.000000	0.000000	INFINITY
GMCOUNT	1.000000	INFINITY	1.000000
MAIZE2	0.000000	8016.812012	6489.087402
CABGS2	0.000000	390768.531250	INFINITY
BTNTS2	0.000000	12730.499023	6936.877930
POTAT2	0.000000	18567.152344	INFINITY
MZSELL2	0.000000	1303.546753	1055.136108
CABSEL2	0.000000	6414.454102	INFINITY
BUTSEL2	0.000000	620.394714	338.054443
POTSEL2	0.000000	608.360168	INFINITY
GM2COUNT	1.000000	INFINITY	1.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
LAND1	5.000000	INFINITY	2.889602
LNDPRP1	7728.799805	INFINITY	709.030212
LBORLP1	73.900002	INFINITY	41.514694

LBORPL1	93.599998	INFINITY	54.548611
LBORWD1	94.379997	INFINITY	4.935620
LBORFI1	88.000000	INFINITY	38.270493
LBORHV1	79.800003	INFINITY	33.255527
SEED1	15677.500000	INFINITY	288.373138
FRTLZR1	14669.339844	0.004335	2303.164551
AGRCHM1	10011.299805	0.001112	2108.687256
IRRGTN1	2900.000000	INFINITY	1490.254517
LNRNTL1	2850.000000	INFINITY	975.427368
HVSTNG1	2976.000000	INFINITY	445.220093
MRKTNG1	18581.509766	INFINITY	0.001500
MZTRNS1	0.000000	INFINITY	2.993696
CBTRNS1	0.000000	INFINITY	46.533474
BTTRNS1	0.000000	INFINITY	0.000000
PTTRNS1	0.000000	INFINITY	0.000000
CAPITAL1	84410.968750	INFINITY	1145.398560
GM1	0.000000	114007.007812	INFINITY
LAND2	5.000000	INFINITY	0.824762
LNDPRP2	11928.799805	INFINITY	2670.311035
LBORLP2	74.099998	INFINITY	5.661527
LBORPL2	92.199997	1.262602	0.028199
LBORWD2	155.500000	0.018140	7.557878
LBORFI2	93.300003	INFINITY	24.438202
LBORHV2	179.100006	INFINITY	3.350841
SEED2	5284.020020	INFINITY	0.996302
FRTLZR2	18929.230469	INFINITY	788.697388
AGRCHM2	4971.109863	INFINITY	111.904739
IRRGTN2	2873.000000	INFINITY	83.941277
LNRNTL2	3980.000000	INFINITY	147.131866
HVSTNG2	8930.000000	INFINITY	2377.573242
MRKTNG2	6537.529785	INFINITY	6537.529785
MZTRNS2	0.000000	INFINITY	7.371998
CBTRNS2	0.000000	INFINITY	0.000000
BTTRNS2	0.000000	INFINITY	40.617290
PTTRNS2	0.000000	INFINITY	0.000000
CAPITAL2	56510.968750	INFINITY	320921.906250
GM2	0.000000	88342.609375	INFINITY

Appendix M: Linear programming model results for a farmer with a large plot

```
NAME
 CANDIDATE OBJECTIVE ROW(S) IS (ARE):
 GM

 EOF IN MPS FILE; LINES READ=      284

 LP OPTIMUM FOUND AT STEP      6

        OBJECTIVE FUNCTION VALUE

       GM)      336108.6

  VARIABLE        VALUE          REDUCED COST
    MAIZE1         0.000000      53733.652344
    CABGS1         2.169885          0.000000
    BTNTS1         0.000000      87110.656250
    POTAT1         0.000000     214205.484375
    SGCAN1         0.000000       8628.668945
   MZSELL1         0.000000          0.000000
   CABSEL1        99.641121          0.000000
   BUTSEL1         0.000000          0.000000
   POTSEL1         0.000000          0.000000
   SUGSEL1         0.000000          0.000000
    TRANS1         0.000000          0.000000
   GMCOUNT    148083.656250          0.000000
    MAIZE2         0.115825          0.000000
    CABGS2         1.538849          0.000000
    BTNTS2         0.769962          0.000000
    POTAT2         0.000000      64967.062500
    SGCAN2         1.280343          0.000000
   MZSELL2         0.712326          0.000000
   CABSEL2        93.161896          0.000000
   BUTSEL2        15.476244          0.000000
   POTSEL2         0.000000          0.000000
   SUGSEL2        14.723944          0.000000
  GM2COUNT    188024.921875          0.000000


       ROW   SLACK OR SURPLUS     DUAL PRICES
    LAND1)         8.200115          0.000000
  LNDPRP1)       366.163025          0.000000
  LBORLP1)        41.785702          0.000000
  LBORPL1)        49.551334          0.000000
  LBORWD1)         0.000000       1568.848999
  LBORFI1)        37.007702          0.000000
  LBORHV1)        27.722759          0.000000
    SEED1)       121.683220          0.000000
  FRTLZR1)         0.646570          0.000000
  AGRCHM1)        15.613582          0.000000
  IRRGTN1)      1450.516724          0.000000
  LNRNTL1)      1172.678833          0.000000
  HVSTNG1)       502.331024          0.000000
  MRKTNG1)       720.703247          0.000000
  MZTRNS1)         0.000000       5400.000000
```

CBTRNS1)	0.000000	2450.000000
BTTRNS1)	0.000000	-1952.079956
PTTRNS1)	0.000000	-2355.000000
SGTRNS1)	0.000000	0.000000
CAPITAL1)	373.875336	0.000000
GM1)	0.000000	-1.000000
LAND2)	6.665021	0.000000
LNDPRP2)	30.114807	0.000000
LBORLP2)	37.364002	0.000000
LBORPL2)	41.637856	0.000000
LBORWD2)	41.711914	0.000000
LBORFI2)	0.483841	0.000000
LBORHV2)	0.008660	0.000000
SEED2)	0.022832	0.000000
FRTLZR2)	0.000000	3.369244
AGRCHM2)	0.000000	4.260521
IRRGTN2)	0.000000	1.379456
LNRNTL2)	655.199219	0.000000
HVSTNG2)	474.497559	0.000000
MRKTNG2)	0.000000	2.830828
MZTRNS2)	0.000000	5724.709961
CBTRNS2)	0.000000	2150.000000
BTTRNS2)	0.000000	2175.000000
PTTRNS2)	0.000000	2355.000000
SGTRNS2)	0.000000	3950.000000
CAPITAL2)	448764.312500	0.000000
GM2)	0.000000	-1.000000

NO. ITERATIONS= 6

RANGES IN WHICH THE BASIS IS UNCHANGED:

		OBJ COEFFICIENT RANGES	
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
MAIZE1	0.000000	53733.652344	INFINITY
CABGS1	0.000000	INFINITY	60258.152344
BTNTS1	0.000000	87110.656250	INFINITY
POTAT1	0.000000	214205.484375	INFINITY
SGCAN1	0.000000	8628.669922	INFINITY
MZSELL1	0.000000	9232.585938	INFINITY
CABSEL1	0.000000	INFINITY	1312.241943
BUTSEL1	0.000000	4355.532715	INFINITY
POTSEL1	0.000000	7200.184570	INFINITY
SUGSEL1	0.000000	0.000000	INFINITY
TRANS1	0.000000	0.000000	INFINITY
GMCOUNT	1.000000	INFINITY	1.000000
MAIZE2	0.000000	1170.602661	6643.337891
CABGS2	0.000000	1895.511597	31647.013672
BTNTS2	0.000000	7230.416504	576.230042
POTAT2	0.000000	64967.062500	INFINITY
SGCAN2	0.000000	34162.097656	2046.153564
MZSELL2	0.000000	190.341904	1080.217529
CABSEL2	0.000000	31.310068	522.745544
BUTSEL2	0.000000	359.722198	28.668163

POTSEL2	0.000000	2170.633545	INFINITY
SUGSEL2	0.000000	2970.617188	177.926392
GM2COUNT	1.000000	INFINITY	1.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
LAND1	10.370000	INFINITY	8.200115
LNDPRP1	7728.799805	INFINITY	366.163025
LBORLP1	73.900002	INFINITY	41.785702
LBORPL1	93.599998	INFINITY	49.551334
LBORWD1	94.389999	0.003698	94.389992
LBORFI1	88.000000	INFINITY	37.007702
LBORHV1	79.800003	INFINITY	27.722759
SEED1	20187.500000	INFINITY	121.683220
FRTLZR1	16503.230469	INFINITY	0.646570
AGRCHM1	14385.200195	INFINITY	15.613582
IRRGTN1	2900.000000	INFINITY	1450.516724
LNRNTL1	2850.000000	INFINITY	1172.678833
HVSTNG1	2976.000000	INFINITY	502.331024
MRKTNG1	23907.009766	INFINITY	720.703247
MZTRNS1	0.000000	INFINITY	0.000000
CBTRNS1	0.000000	INFINITY	60.442310
BTTRNS1	0.000000	75.859421	0.000000
PTTRNS1	0.000000	62.880535	0.000000
SGTRNS1	0.000000	0.000000	0.000000
CAPITAL1	96410.968750	INFINITY	373.875336
GM1	0.000000	148083.656250	INFINITY
LAND2	10.370000	INFINITY	6.665021
LNDPRP2	7928.799805	INFINITY	30.114807
LBORLP2	73.900002	INFINITY	37.364002
LBORPL2	93.599998	INFINITY	41.637856
LBORWD2	150.500000	INFINITY	41.711914
LBORFI2	127.000000	INFINITY	0.483841
LBORHV2	103.800003	INFINITY	0.008660
SEED2	12999.799805	INFINITY	0.022832
FRTLZR2	17041.230469	0.018802	0.567375
AGRCHM2	8834.200195	0.267584	0.070906
IRRGTN2	2900.000000	0.086624	0.004502
LNRNTL2	3850.000000	INFINITY	655.199219
HVSTNG2	6030.000000	INFINITY	474.497559
MRKTNG2	31429.009766	0.072803	1.284289
MZTRNS2	0.000000	INFINITY	0.712326
CBTRNS2	0.000000	INFINITY	87.453453
BTTRNS2	0.000000	INFINITY	15.476244
PTTRNS2	0.000000	INFINITY	0.000000
SGTRNS2	0.000000	INFINITY	14.723944
CAPITAL2	46510.968750	INFINITY	448764.312500
GM2	0.000000	188024.921875	INFINITY