DECLARATION

I, **Linia Ngunguzala**, declare that **"ESTIMATION OF THE OPTIMUM CROP MIX GIVEN THE INTRODUCTION OF CHILI PRODUCTION AND MARKETING IN GOROMONZI AND MARONDERA DISTRICTS, MASHONALAND-EAST, ZIMBABWE"** is a product of my own research work, and all other sources of material are duly acknowledged. This work has not been submitted to any other institution for an award of any academic degree.

…………………………………………………………………………..

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DEDICATION

To my husband and best friend ever, Christian and our lovely daughter Anotidaishe Tamah.

ABSTRACT

Choosing the optimal cropping or enterprise mix has undoubtedly been one of the greatest challenges facing farmers due to multiple objectives such as food security, cash requirements, profit maximization etc. Farmers find it difficult to choose an optimal cropping or enterprise mix given the multiple objectives faced by farmers and often continuous changing farming systems and profitability. As a result, decision making has become more and more difficult in agriculture requiring sophisticated techniques and methods to help in decision making.

Several methods have been used in empirical studies to help farmers in decision making especially on optimal crop mix. This critical decision is made by each farmer at the beginning of each season. Maximizing profits leads to the same decision rule as minimizing costs of production. The production theory defines output or production as a function of several inputs such as land, labor, capital and management. These factors influence production and household resource allocation. There are several research methods that have been identified in the literature. The methods reviewed vary from gross margin to linear programming models. Linear programming might be preferred where the choice was made among many alternatives and high accuracy needed because it enables even a less skilled worker to reach optimum solution.

Chapter 3 presented the research methods which were going to be used to achieve my objectives. Introduction of a new enterprise affected resource allocation as farmers re-organized resource use to accommodate new enterprise and increase income. The analytical framework consisted of gross margin and linear programming analysis. The main objective of this study was to estimate the optimal cropping or enterprise mix that would result with the introduction of organic chili production in the districts of Goromonzi and Marondera, in

Mashonaland-East province in Zimbabwe. Preliminary analysis showed chili, ground nuts, and sugar beans and maize with about US$380, US$349, US$180 and US$53 gross margin budgets respectively.

Although preliminary analysis was necessary to understand the socio-economic characteristics of the two districts, and have these socio-economic characteristics would affect agricultural output given the level of function of production and given level of technology. Further detailed analysis was required to understand the optimal cropping enterprise mix in the two districts. Linear programming estimation was therefore carried out to estimate the optimal crop mix for an average farmer in the two districts.

Linear programming analysis was used to explore optimum crop mix for the average farmer. The optimum crop mix is 0.2 acres, 0.3 acres, 5.5 acres and 0 acres of ground nuts, sugar beans, chili and maize respectively. The optimal crop gross return is US$3082. Finally, sensitivity analysis was carried out. It showed that a percentage increase in land resulted in increase in area under. Areas under the other crops remained the same. Further sensitivity analysis showed that a percentage change in labor resulted in a decrease in the gross return. However there were no factor movements both at 5 % and 10 % change.

Important recommendations from the empirical findings were that there is need for the government to provide extension services and support services such as road networks and an enabling environment for production of crops. NGOs to increase extension and training programmes to farmers in contract negotiations and also they should continue to source for better markets and training to increase production performances. Farmers should form marketing groups.

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ACRONYMS AND ABBREVIATIONS

AREX	Department of Research and Extension
BRM	Binary Response Model
OLS	Ordinary Least Squares
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GI	Gross Income
GM	Gross Margin
GMA	Gross Margin Analysis
Kg	Kilogram
LRM	Linear Regression Model
MLRM	Multiple Linear Regression Model
SPSS 18	Statistical Package for Social Scientist version 18
TVC	Total Variable Cost

CHAPTER

1 INTRODUCTION

1.1 Background Statement

Several criteria are used to come up with optimal crop/livestock enterprise mix. These range from simple to complicated analytical tools such as gross margin budgets, cost benefit analysis, linear programming and parametric programming. Smallholder farmers normally depend on the knowledge about historical events in making decisions whereas commercial farmers can sometimes use decisive complicated methods to make their decisions.

For the smallholder subsector, the difference is not only found in farm sizes but also in the allocation of resources to food, cash crops, livestock and off-farm activities, in the use of external inputs and hired labor, the proportion of food crops which are sold, and in the expenditure patterns (Bijman et. al., 2007). For example, large scale commercial farmers might want to maximize profits whereas smallholder farmers might want to maximize food security or income or diversify risk.

The actual farming pattern, household strategies and behavior, and the livelihood pattern are determined by resource endowments and institutional factors such as access to markets, provision of hybrid seeds, extension and economic factors such as organization of markets and information on prices and availability of markets. Tinsely (2004) contents that farmers have limited education, however they are skilled practitioners of agronomy and animal production.

The Bird's Eye chili plant has a productive life of two to three years and can be intercropped with herbs and spices (IDEA, 2001). Normally the seed bed is prepared in January incorporating animal manure and about 20 grams of seed which gives at least 500 good plants. Transplanting to farmers' fields in done late March with a recommended spacing of 1 m within rows and 1 m between rows for pure stand production. When intercropping with other crops, the spacing has to be 2 m by 2m. Harvesting and drying commences from June right through to August.

On well-managed farms, yields of at least 300 grams of fresh chili per plant per year or 180 grams of dried chili are expected. At a density of 10,000 plants/ha this will translate to a yield of 1.8 tones/ha, equivalent to a cost insurance and freight (CIF) value of more than $5,000/ha for grower-exporters as at March 1997 prices (IDEA, 2001). Harvesting is the most labor intensive activity in chili production. Therefore it is far more profitable to harvest all the fruit from a few plants than half of the fruit from many plants. Moreover, the need for seasonal labor and good labor management has been a deterrent to large scale production of bird's eye chili (IDEA, 2001).

Kaite, a nongovernmental organization introduced chili production in Marondera and Goromonzi Districts using organic methods in 2006. Organic farming methods reduce costs of production and increases revenue (Firth, 2004). For example, a project which introduces chili productions using organic fertilizer, which is cheaper, and contracts its prices and market, guarantees income. The guaranteed price and income is likely to promote adoption of chili production. Introduction of organic chili results in changes in relative costs of factors of production, which induces movements in factors of production, which are land, labor and capital. For example, we would expect land, labor and capital to move into chili production moving away from enterprises with less return. This will lead to new optimum crop/livestock mixes. However, for the farmer to come to this new optimum enterprise mix, there are several methods which determine pace of adoption.

Organic agriculture has become more widespread globally, as the market for certified organic agricultural products has grown over the recent years (FAO, 2002). This has given smallholder farmers a window of opportunity for guaranteed high value prices, and has attracted smallholder farmers to also venture into these high value crops such as chili using organic methods (IDEA, 2001; FAOSTAT, 2011). Organic farming has been found to be cost effective, affordable improves liquidity management, and provides more employment opportunities (Adhikari, 2009; Svotwa et. al., 2007). Suffer (2004) contents that organic farming contributes directly to rural economic development. For example, through direct sales of produce to local businesses and local community. Scialabba (2007) contents that communal farmers can benefit from improved agro-ecological management of traditional agriculture using low external input and inexpensive technologies such as organic farming.

1.2 Problem Statement

Smallholder farmers are characterized by low investment capacity, low resources, low agricultural productivity and varying incomes (Mujeyi, 2007). An introduction of high value cash crops such as chili can increase farmer's income, food security and satisfy other objectives (IDEA, 2000). However, any new crop diversification program will bring with it several disturbances in terms of shifts in resource uses with resources shifting from one crop enterprise to the other and inducement of technological changes. Introduction of a cash crop such as chili is expected to increase household income diversification for smallholder cash constrained farmers (Ibrahim, 2007).

Kaite is a private company. It introduced chili production in the Districts of Goromonzi and Marondera of Mashonaland-East in 2006. The project guaranteed markets and prices through a contract. The project also provided seed and the extension services. However, when the innovation was introduced, chili production quickly expanded because lucrative because farmers were given inputs on credit with a guaranteed market and price. In their decision making, farmers in the two Districts soon found out that they had to use their resources to produce chili and other crops.

It was observed that the farmer’s crop mix had changed. Although these changes in crop mix would be seen overtime, a priori, it could always be difficult to foretell resource movements and technological adoption.

Kaite introduced chili production to Marondera and Goromonzi Districts with the objective of increasing farmer’s incomes. However, a priori, no study had been done to see whether chili production should be part of the optimum crop enterprise mix in these two Districts. The private company however subsidized the crop by providing free seed, guaranteed markets, free credit for inputs and extension services. The current average crop mix grown in these two Districts is therefore a result of the current uneven resources mix. We would want to level what would happen if the playing field was even for all crops.

1.3 Research Objectives, Questions and Hypotheses

The main objective of this thesis is therefore to estimate the optimal crop mix for an average farmer in Marondera and Goromonzi Districts given the introduction of chili. Chilies are produced using organic practices, marketed through a guaranteed contract which provides a market and credit inputs. The decision of the optimal crop mix is dynamic since the decision is made repeatedly at the beginning of every season. As the socio-economic, institutional and technical conditions change, the optimal crop and livestock enterprise mix at the farm changes too. The study will therefore seek to satisfy the following specific objectives,

Objectives

i. Estimate average gross margin budgets for major crops grown in Goromonzi and Marondera Districts where chili production has been introduced by Kaite;
ii. Use linear programming to estimate optimal crop mix for the average farmer in Goromonzi and Marondera Districts; and
iii. Make policy recommendations about introduction of chilies in the production systems of Goromonzi and Marondera Districts.

Questions

The specific objectives will be answered by asking the following questions or consistence;

i. What are the average gross margin budgets for major crops grown by farmers in Goromonzi and Marondera Districts?
ii. What is the optimal crop mix for the average farmer in Marondera and Goromonzi Districts and
iii. What are the policy recommendations about the introduction of chilies to the production systems of Goromonzi and Marondera districts?

Hypothesis

In order to answer the above questions, the following null hypotheses are going to be tested;

i. The average gross margin for chili is relatively higher compared to other crops;

ii. There is going to be a substitution of factors of production in favor of chili and increase in overall income of the average farmer in Goromonzi and Marondera Districts; and

iii. Government policy can play a role in favor of increased chili production.

1.4 Organisation of Thesis

This thesis is organised into seven chapters. The first chapter covers the introduction and background about the issue to be studied. The main objective of the thesis is to estimate the optimal crop mix for an average farmer in Goromonzi and Marondera Distircts, Mashonaland-East.

The second chapter provides literature review. The literature reviews the theory of production and resource allocation in smallholder farming systems. The review also looks at adoption process of new technologies. The chapter also provides an overview of factors influencing chili production in Zimbabwe as well as empirical tools commonly used in estimating optimal crop mix in farming system.

The third chapter provides an outline of the research methods used in the study. The study used gross margin budget analysis and linear programming to estimate the optimal crop mix. Chapter 4 provided the preliminary analysis of the research data. The analysis tests the first hypothesis and finds out that indeed chili production had the highest gross margin of US$380 given US$129 for maize, US$349 for ground nuts and US$180 for sugar beans.

Chapter 5 estimates the optimal crop mix for an average farmer in Goromonzi and Marondera Districts in 2010. The chapter also provides some sensitivity analysis at 5% and 10%

changes. Sensitivity analysis shows that land moved to chili with increase in land brought under production. Chapter 6 contains the discussion of the results found in chapter 4 and 5 and policy recommendations. Chapter 7 provides conclusion.

CHAPTER

2 LITERATURE REVIEW

2.1 Introduction

The main objective of this chapter is to provide a detailed literature review on the economics of crop production, evaluate factors influencing crop production, evaluate methods used in similar studies on the economics of crop production, and get insights on theoretical and policy issues, and other issues surrounding crop production. The chapter starts by reviewing the economics of crop production, focusing on the production theory and using chili production in Goromonzi and Marondera Districts as examples. Production theory defines output or production as a function of several inputs, such as land, labour, capital and management (Oluwatayo *et al.,* 2008). These factors of production can be both varied or fixed depending on the time frame, that is short run, medium run or long run, and depending on space, that is, extensive or intensive, particularly in Zimbabwe.

The major factors or inputs or resources which influence production are land, labour, capital and management (Binam *et al.,* 2004; Sojkova *et al.,* 2007). The level of education of the household head, farming experience, frequency of extension visits and access to credit have an impact on economic efficiency in production. Increase in human capital enhances productivity because farmers are better able to allocate labor and purchased inputs. It also enhances farmer's ability to receive and understand information relating to new technology. The section further analyses the relationship between factors of production and production. Farmers with more years in school, have access to credit, and are members of associations have increased productivity.

The chapter further looks at research methods which have been used in the literature to determine optimum crop or enterprise mix on the farm. Every farmer is faced with a problem of deciding the enterprise mix during the beginning of every season, and by so doing allocating the scarce resources available to him (Sirohi *et al.,* 1968). There are several methods in the decision making process starting from rudimentary methods, historical experiences to sophisticated methods such as cost benefit analysis, gross margin budget analysis, linear programming, nonlinear programming and other decision making methods.

Finally, the chapter discusses about the experiences of policy implications emerging from these studies and areas for further research and insights into the evaluation process.

2.2 The Economics of Crop Production

Production is the processes and methods employed to transform tangible factors/ resources or inputs namely raw materials, semi-finished goods; or sub-assemblies, and tangible inputs such as ideas, information and knowledge into goods and services or output (Oluwatayo *et. al.,* 2008). These resources can be organized into a farm-firm or producing unit whose ultimate objectives maybe profit maximization, output maximization, cost minimization or utility maximization or a combination of these objectives four. In this production process the manager or entrepreneur may be concerned with efficiency in the use of the factor inputs to achieve optimum crop mix.

The basic theory of production is thus simply an application of constrained optimization. The farm-unit attempts either to minimize the costs of producing a given level of output or maximize output attainable with a given level of costs (Oluwatayo *et. al*., 2008). Both optimization problems lead to the same rule for the allocation of inputs and choice of technology. Since there are alternative means of attaining the production goals, the theory of production presents the theoretical and empirical framework that facilitates a proper selection among alternatives so that any one or a combination of farmer's objectives can be attained.

Certain parameters have to be known for one to understand how farmers make their decisions that enable them to attain their goals. These parameters can be shown through a production function, which shows the technical relationship between factor inputs and outputs involved in the production process. The basic assumptions of production function are presented in two graphs. The first represents output as a function of input and introduces the three stages of production Let y = output and x = input. The production function is y = f(x); marginal productivity (MP) is $f_x = \delta f/\delta x$; and average product (AP) is y/x. Recall that

MP > AP > 0;	at Stage I of production function
AP >MP >= 0;	at Stage II of Production function, and
MP < 0;	at Stage III of production function

The second stage is the economic region. This is the stage with positive but decreasing marginal productivity or concave production function. A competitive profit maximizing firm is likely to operate at this stage of the production function. Many mathematical specifications of production functions, like for example the Cobb-Douglas: $y = Ax^a$, with $0 < \alpha < 1$, only represent situations when all outcomes are at the economic regions. Their use precludes identifying situations in which producers operate at the third stage of production and have negative marginal productivity. Quadratic production functions, $y = a + bx - cx^2$, allow outcomes at the second and third regions of production functions, but not at the first. A simple and elegant production function which allows three regions of production is not easy to construct, so we use simple, elegant but flawed production function specifications in many analyses.

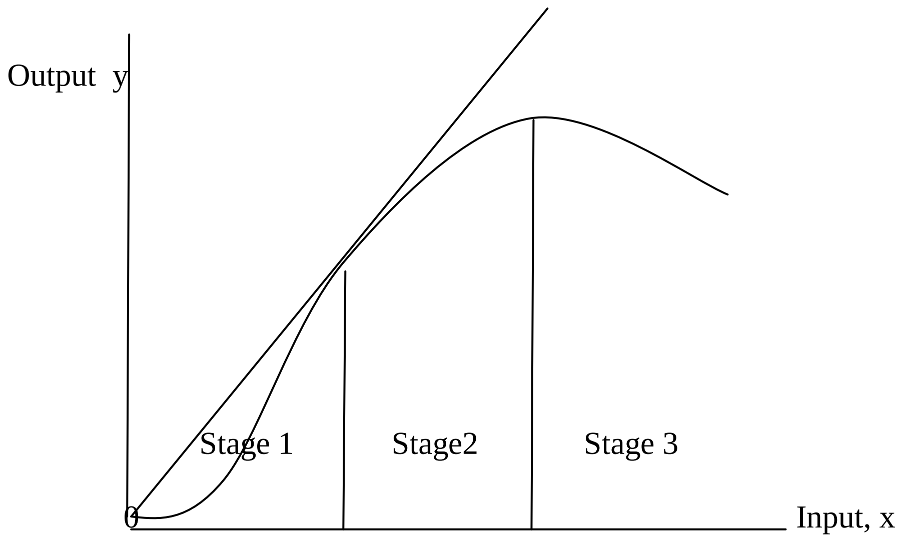

Figure 2.1: Three stages of Production

Source: Sojkova *et al.*, 2007

Figure 2.1 addresses the relationships between output and input in the production process. A basic issue it raises is that of economies of scale. It represents the assumption that below a certain level of output (stage 1), there is increasing returns to scale. However, at the economic region, there is constant, or more likely decreasing returns to scale.

Figure 2.2 represents the relationship between inputs in the production process. The isoquants depicted represents the different input level combinations producing the same level of output. Isoquants are useful to address issues such as input intensity and input substitutability. If X_1 is capital and X_2 is labor, X_1/X_2 measures capital intensity (relative to labor). Production at point A is capital intensive and at B is labor intensive.

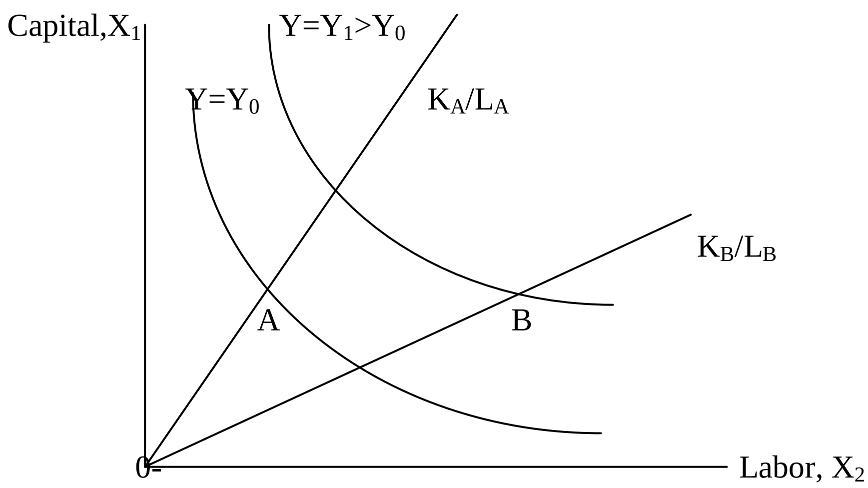

Figure 2.2: Isoquants and Factor intensity

Source: Sojkova *et al.,* 2007

Based on neo-classical production theory, the dependent variable of the production function should be expressed as the quantity of a given output produced in a given time period as a result of a production transformation of a given input quantity (Sojkova *et. al*., 2007). This definition is followed by the first endogenous variable specification of the stochastic frontier production model, namely the output is the amount of a produced commodity in a farm (farm enterprises production), expressed in tons.

By using this production definition, we assume that the production quantity is homogenous when comparing the analyzed enterprises. Constructing a production function requires further information about inputs equipment in quantity references. Because only cost data is available for production factors, no breakdown between quantity and prices is possible. The agricultural production process is a complex activity where not only inputs quantity, but also input quality and functionality have a significant impact on input performance (Oluwatayo *et al.,* 2008).

2.3 Factors Influencing Crop Production

Nyagaka *et al*., (2009) did a study on economic efficiency of potato production in Kenya and found out that the level of education of the household head, experience, number of extension visits, and access to credit are significant variables for improving the level of economic efficiency of potato production. The positive impact of education on economic efficiency indicates that increase in human capital will enhance the farmer's ability to receive and understand information relating to new agricultural technology. This finding supports argument by several authors that an increase in human capital will augment the productivity of farmers since they will be better able to allocate family-supplied and purchased inputs, select the appropriate quantities of purchased inputs and choose among available techniques (Sirohi *et al.*, 1968; Binam *et al*., 2004).

A study by Nyagaka *et al*., (2009) revealed that economic efficiency increases with the number of years spent in potato production by the household head. This suggests that farming is highly dependent on the experience of farmers which may lead to better managerial skills being acquired over time. Farm households who receive regular extension visits by extension workers are more economically efficient than their counterparts. Thus economic efficiency increases with the number of visits made to the farm household by extension workers. Nchare (2007) supports this argument when he indicated that regular contact with extension workers facilitates practical use of modern techniques and adoption of improved agronomic production practices.

Farmers with access to credit tend to exhibit higher levels of economic efficiency and are able to better allocate their limited resources among competing alternatives (Nyagaka *et al*., 2009). So access to credit permits a farmer to enhance production by overcoming these liquidity constraints. Liquidity constraints may affect farmer's ability to apply inputs and implement farm management decisions on time. The use of credit therefore ensures timely acquisition and use of inputs and results in increased economic efficiency. Binam *et al.*, (2004) used farm-specific variables to explain technical inefficiencies. Their results revealed that those farmers who have more than four years of schooling, better access to credit, located in fertile regions and those who are members to farmers' club or association tend to be more efficient. The distance of the plot from the main access road and the extension services have a negative influence in increasing technical efficiency in different farming systems (Binam *et al.*, 2004).

Sojkova *et al.*, (2007) used four inputs variables and one output of the stochastic frontier production models for the analysis of Slovak farm enterprises: capital, labor, material and agricultural land as inputs and total production as the output. However, under organic systems crops rely on ecologically based practices, such as biological pest management and composting, and the exclusion of synthetic chemicals. The fundamental components and natural processes of ecosystems such as soil organism activities, nutrient cycling, and species distribution and competition are used as farm management tools (McBride *et al.*, 2008). For example, crops are rotated, food and shelter are provided for the predators and parasites of crop pests, animal manure and crop residues are cycled and planting/ harvesting dates are carefully timed.

The role of social capital in providing incentives for efficient production is revealed by the negative and statistically significant relationship between club membership of a household member and technical inefficiency in Binam *et al.*, (2004). Farmers that are club members can be very valuable for small-scale operations, because it facilitates access to markets and increases income and employment for growers. In addition club members provide farmers with a secure market for their crops as well as some technical assistance: source of farmer technical efficiency. A study done by Ibrahim *et al.,* (2010) using a partial budgeting analysis for the alternative *Striga* control revealed that the costs of fertilizer and labor accounted for a substantial part of the total costs of the five treatments. Fertilizer cost ranged between 38-54% while labor cost ranged between 41% and 55% across the five treatments respectively. Linear regression analysis revealed that all variables in the model had positive regression coefficient indicating direct relationship between each of them and the output of maize (Onuk *et al*., 2010).

Labor inputs by household members are often higher in cash than food crops. The income and nutritional effects of shifts from subsistence to commercialized crop production may be highly time and place-specific, as a review of some evaluations of cash cropping schemes has indicated (Immink *et. al.,* 1991). The broad findings of these studies indicate that a shift towards commercialized crop production such as chili involves significant reallocation and increased productivity of household resources, particularly land and labor, and is associated with significant increases in household income.

2.4 Research Methods for Evaluating the Economics of Crop Production

The use of gross margins became widespread in the UK from about 1960, when it was first popularized amongst farm management advisers for analysis and planning purposes (Firth, 2011). The gross margin per hectare or per head for crops and livestock can be compared with 'standards', published averages of what might be typically possible in average conditions) obtained from other farms. Gross margins, however, should only be compared with figures from farms with similar characteristics and production systems. With this reservation in mind, the comparisons can give a useful indication of the production and economic efficiency of an enterprise. In organic systems gross margins are also useful for farm planning and for making comparisons of enterprises, on the same farm, between organic holdings, or between conventional and organic enterprises holdings (Firth, 2011).

Gross Margin Analysis (GMA) provides a more convenient and simple way to summarize information required in determining the financial performance of a farm enterprise. Onuk et. al., (2010) did an economic analysis using gross margin and the results revealed that maize has established itself as a very significant component in the smallholder farming system of Nigeria and is determining the cropping pattern of the farmers. IDEA, (2001) used gross margins to evaluate performance of chili in smallholder farmers and found them to be profitable because of the low investment costs. Expenses incurred were for seeds, land cultivation, fertilizers, chemicals, labor and processing.

Ebukiba (2010) did a study to evaluate the economic analysis of cassava production in Eket local government area of Akwa Ibom State of Nigeria using gross margin analysis. Gross Margin Analysis was used to analyze the cost and return data, the result reveals that for a hectare of sole cassava the gross margin was N141,950 giving a cost benefit ratio of N1.90; N1.00 implying that cassava production is profitable. Ibrahim et. al., (2010) conducted a study to compare economic performance of five *Striga* control methods in Nigeria using gross margin analysis. The results revealed that treatment plots involving the cultivation of *Striga* tolerant maize variety followed by *Striga* tolerant maize variety in the second year (T1) had a higher cumulative gross margin per hectare (N76, 884.61) followed by the treatment involving the cultivation of an improved soya bean variety (TGX 1448-2E) followed by *Striga* tolerant maize variety in the second year i.e.T2 (N36, 287.00). The marginal rate of return was also higher for T1 (N885.00) followed by T2 (N8.90) (Ebukiba, 2010).

Ranadhawa *et. al.*, (1966) applied inter-regional programming model to determine an optimal allocation of land among different crops and regions of India. They used gross returns to develop optimal production pattern but found that it would be better if net returns were used in the analysis. They also pointed that cash costs in their study formed a small proportion of the total cost and then reported that the situation had changed and the proportion of variable cost to the total cost had increased and the concept of gross returns seemed to have lost its relevance (Ranadhawa *et al.*, 1966).

Papst *et al.*, (1970) used linear programming technique to develop farm plans for a 470-acre model farm in Mason County, Illinois. The results showed that the farm plans gave the highest net return above variable costs for each of four basic situations: no irrigation, 150 acres irrigated, 287 acres irrigated, and 437 acres irrigated. The highest return plans were found to be relatively insensitive to changes in relative prices and yields. There was a declining rate of return on added investment in irrigation equipment as the area irrigated increased; the rate of return on equipment to irrigate the first 150 acres was 37 percent, while the rate of return on the added investment necessary to irrigate 150 additional acres from a base of 287 acres was only 7 percent.

Ibrahim (2007) did a study to determine the optimal maize-based enterprise in soba local government area of Kaduna state, Nigeria. The linear programming analysis indicated that a gross margin of N56, 920,30 was obtained in the planned farm as against N26,282.00, per hectare of maize/cowpea in the unplanned farm. Curtis *et al*., (2009) used data on current and alternative crops such as enterprise budgets, producer interviews and field trials in North Western Nevada USA. They used an EPIC Model which synthesizes both agronomics and economics, to model yields and returns of alternative crops under differing irrigation levels. This study determined that the alternative crops that could be feasibly substituted for alfa alfa and reduce water use by half while providing net returns that meet or exceed returns from alfa alfa and keep producers profitable.

Cashdollar (1971) used linear programming analysis to determine the most profitable crops grown on representative farms under two sets of localization regulations for the Fortieth Distributary in Mysore state, India. The results showed that in situations of limited operating capital, the dry land crops compete favorably with irrigated crops, primarily because of the higher returns per rupee invested in cash inputs on the dry land crops. It was found that paddy competes favourably with the light irrigated crops where developed land and capital are plentiful. However, when developed land is limited it is generally more profitable to double crop with two light irrigated short duration crops than to grow one crop of longer duration paddy.

Sirohi *et al.*, (1968) assessed the possibility of increasing net farm returns through reorganization of resources by employing linear programming. The results of their study showed that by reallocation of resources, net farm returns could be increased to the extent of 24 to 42 per cent. Singh (1970) used linear programming technique to know the possibilities of increasing the income and labor absorption through optimal combinations of crop and dairy enterprises. He developed optimum plans under existing as well as improved technology with limited and unlimited capital. He concluded that inclusion of dairy was profitable with both the limited and unlimited capital situation.

Linear programming techniques were employed to assess the impact of dairy enterprise on productivity and employment by Singh *et al.,* (1977). They concluded that the normative plans developed with and without dairy not only affected the productivity and employment but also the requirements of capital and credit on the farms. The capital and credit requirements increased with the dairy activity. It was also found in the optimum plans, two buffaloes for small; three for medium and eight for large farmers to be necessary to maximize their net farm returns. Singh *et al.,* (1977) used a similar technique to study the impact of varying levels of dairy enterprise with crop farming on income and employment. They concluded that the farm income and labour use could be increased through optimization of resource use under different farm situations.

To develop optimum farm plans for subsistence and commercial farmers in Bangalore District, a linear programming technique was applied by Ramanna, (1966). He reported that a substantial increase in net farm returns could be realized by proper reorganization of available resources even with the available technology. He also pointed out the prospects of higher net farm returns under improved technology with additional resources. Nadda *et al.* (1978) explored the possibilities of optimizing farm returns for the farmers of different zones in Himachal Pradesh. They concluded that existing cropping pattern where diversification of agriculture observed was found sub-optimal. The normative cropping pattern involved fewer crops, indicating a tendency towards specialization.

The impact of optimal allocation of supervised production credit on different farm size groups was assessed by employing linear programming by Arora *et al., (*1978). The results revealed that the gains of optimal credit allocation were more on small farms followed by medium and large farms. Thore *et al.,* (1985) used linear programming to study the impact of dairy enterprise on costs and returns and concluded that mixed farming with dairy had a positive effect on the income of the farmers in all the size groups. Singh *et al.*, (1988) employed linear programming to integrate improved technology of crop and dairy production for increasing income and employment. They concluded that the optimization of resources under different farm plans resulted in increased income on marginal, small, medium and large farms. Adoption of improved technology in both the crop and dairy production increased the income of the farmers by 116 per cent for small farmer to 232 per cent for marginal farmers as compared to the existing plan.

Sastry (1993) applied linear programming to develop optimum enterprise system for farmers in Chittoor District, Andhra Pradesh. They indicated greater scope for increasing the net farm income on small farms by mere reorganization of resources even under existing technology with available funds. Further, they found that the effect of optimization of resources at existing technology, both under restricted and unrestricted capital was insignificant on large farms. Lakshmi, (1995) used linear programming to determine the income and employment prospects of farmers in Chandragiri Mandal of Chittoor District. The study indicated that the simultaneous provision of credit and adoption of new technology would enhance the income and employment opportunities on small and large farms.

By using linear programming technique, another author developed optimum crop and dairy mix for farmers in Bangalore district in India (Reddy, 1979). The results of the study indicated one cross bred cow for small farmers, one cross bred cow and one local buffalo for medium farmers and none for large farmers in normative plans of crop and dairy mix. As a result the net farm returns increased by 45.77 per cent for small, 42.25 per cent for medium and 57.88 per cent of large farmers over existing plan. He concluded that the introduction of dairy along with crops would be more profitable only in case of small and medium farmers.

Reddy, (1980) employed linear programming tool to examine the income and employment potential on small farms in Bangalore district, Karnataka. It was observed that the net farm return increased to the extent of 50 and 16 per cent on unirrigated and irrigated small farms respectively by mere reallocation of resources at existing technology. The results also indicated the prospects of raising the income by 110 per cent on unirrigated farms and, by 14 per cent on irrigated farms, when capital constraint is relaxed. Singh *et al.* (1972) in their study on production possibilities and resource use pattern on small farms in three regions of Uttar Pradesh examined the prospects of increasing farm income through better resource allocation. It was observed that the farm resources were not utilized optimally under existing cropping pattern and reorganization of production programme would increase the farm income even under the existing resource availability.

2.5 Lessons Learnt from the Literature Review

Increase in human capital leads to increased productivity since farmers will better allocate their resources and choose among available resources. Farmers acquire better managerial skills over time thus farming is highly dependent on experience of farmers. Frequency of extension contact has a positive effect on adoption of improved techniques and their practical use (Nyagaka *et al*., 2009). Availability of credit eliminates liquidity constraints hence increasing farmer's ability to apply inputs and implement farm decisions on time. Social capital plays a significant role in increasing productivity of the farmer. Farmer associations facilitate access to markets resulting in increase in income for its members. It also provides secure markets for crops as well as technical assistance (Binam *et al*., 2004).

Firth, (2011) noted that gross margin should be compared with figures from farms with similar characteristics and production systems. Moreover, gross margin analysis is useful for farm planning and for making comparisons of enterprises on the same farm and for determining the financial performance of a farm enterprise. Ranadhawa *e. al.,* (1966) reported that gross returns lost its relevance in a study they did to determine an optimal allocation of land among different crops and regions. They concluded that use of net returns provides better results in developing optimal production patterns.

Regardless of its convenience and simplicity, GMA has its own limitations. Gross margins do not tell whether a particular way of producing an enterprise is optimal, most profitable, or best way of producing that crop. They only tell about net returns on resources employed in producing the crop. Positive gross margin values do not necessarily mean that the enterprise is technically efficient in producing the crop. It is very difficult to tell, with a GMA, why an enterprise might have positive margins but fail to attract satisfactory investment by farmers (adoption) in terms of resource allocation. Finally, GMA fails to take into account potential social and environmental impacts as a result of implementing activities of the production enterprise. Such impacts can be considered by assigning values to the social and environmental benefits, costs and including them, in the GMA. These benefits and costs are usually not included due to difficulties in measuring and computing them.

Kahlon *et. al.,* (1962) in their study on the application of budgeting and linear programming in farm management analysis reported that linear programming might be preferred where the choice was to be made among many alternatives and high accuracy needed, that enabled even a less skilled worker to reach an optimum solution. Therefore, linear programming is considered a useful tool of farm management analysis even in under developed countries. These findings have much support from other writers who stated that the linear programming offers a great scope for its usage with advantage and even alternative plans could be worked out for different prices (Desai, 1962; Malya, 1962; Ramanna, 1966). They concluded that the pressing need for reorganization of the limited resources made the application of linear programming, a necessary step towards efficient farm business management.

2.6 Conclusion

The objective of this chapter was to carry out a detailed literature review on the economics of crop production and the methods that have been used in empirical studies to decide on optimal crop mix. This critical decision is made by each farmer at the beginning of the season using several methods. The chapter starts by describing duality in economics of production, that is maximizing profits leading to the same decision rule as minimizing costs of production. The production theory defines output or production as a function of several inputs such as land, labour, capital and management. These factors of production can be both varied or fixed depending on the time frame, that is short-run, medium-run or long-run, and depending on space, that is, extensive or intensive particularly in Zimbabwe.

The chapter further looks at factors influencing production and household resource allocation. The major factors or inputs or resources which influence production are land, labor, capital and management. The level of education of the household head, farming experience, frequencies of extension visits and access to credit also affects production. Increase in human capital enhances productivity since farmers are better able to allocate labor and purchased inputs, and it also enhances farmer’s ability to receive and understand information relating to new technology. The section further analyzed the relationship between factors of production and production. Farmers with more years in school have access to credit and have membership of association have increased productivity

There are several research methods that have been identified in the literature. The methods reviewed varied from gross margin to linear programming models. Gross margin analysis is useful for farm planning, for making comparisons of enterprises on the same farm and determining the financial performance of a farm enterprise. Linear programming has been used in crop-livestock enterprise mixes to explore possibilities of increasing income and labor absorption through optimal combinations.

Further, the chapter reviewed the empirical studies that have been done to estimate optimal crop/enterprise mix at farm level. Linear programming has been used by several authors to develop optimum enterprise systems on farms. The results showed that net farm income can be increased by reorganization of resources under existing technologies and funds. There are prospects of higher net farm returns under improved technologies with additional resources.

Finally, the chapter looked at the lessons learnt from the literature review. The impact on each factor depended on place and space. Regular extension contact facilitates adoption and practical use of improved production technologies. It is very difficult to tell with GMA, why an enterprise might have positive margins but fail to attract satisfactory investment by farmers in terms of resource allocation. Gross Margin Analysis has weakness. Linear programming has weakness also, so it is better to use both methods. The pressing need of reorganization of the limited resources made the application of linear programming a necessary step towards efficient farm business management.

CHAPTER

3 RESEARCH METHODS

3.1 Introduction

Chapter 3 presents research methods. The chapter provides the conceptual framework that will be used in showing the different relationships between the economic variables and the analytical framework that will be used to analyze the data set, and present the expected results from the theoretical model. The chapter starts by describing the conceptual framework that has been developed for this thesis. The conceptual framework relates different concepts from theory to show the relationships between different economic variables. For example, introduction of a new enterprise affect resource allocation as farmers shift some of the resource to accommodate the new enterprise.

The chapter further looks at the analytical framework that will be employed in analyzing the data. Gross Margin Analysis is an input into linear programming analysis. It is an analytical tool used in financial analysis to determine performance of agricultural enterprises. However, gross margin is not a decision tool because increases in margin will also results in increase in the relative costs. Thus at any particular gross margin there is a corresponding cost structure. Results of gross margin analysis are further used in linear programming analysis to estimate the optimal enterprise mix at farm level.

Finally, the chapter presents the expected results from the theoretical model. Average gross margin for chili is relatively high compared to other crops. Chili uses minimum purchased resources, variable costs associated with the production of the crop will be low compared to other crops hence a higher and positive gross margin since production is subsidized. Substitution of land use in favor of chili production and increase in overall income of the farmer is expected. Finally, linear programming analysis in next chapter will test the optimal mix given introduction of chili in the production system in Goromonzi and Marondera Districts.

3.2 Conceptual Framework

An optimum crop mix is situation where a farmer's objective is to maximize gross income given some level of resource. Introduction of chili redistributes resource allocation and crop mixes for the farmers. In the process it is expected that it enhances income, creates employment and method of production is cost effective especially for rural communities (Ranadhawa *et al.*, 1966).

Chili production has proved to be a worthwhile enterprise for smallholder farmers in developing countries such as Uganda (IDEA, 2001). Inputs such as fertilizers, seed, land, manure, pesticides have been used to produce chili. However, the production system has been influenced by chili characteristic among other factors such as organic practices being employed, farmer's characteristics such as sex, experience in chili farming, and education of household and resource endowment (Sirohi *et al.*, 1968). All these factors determine the quality and quantity of chili being produced by the farmer, hence the profit margin that can be realized by the farmer. Chili with a high pungency and are red receive premium prices on the market. The production method used in producing the chili of employing organic methods is highly labor intensive and this has an effect on the variable costs as labor costs are very high relative to other costs (IDEA, 2001).

Choice of and participation in chili production is influenced by the farmers' access to social, economic and financial resources such as land, labour, capital and frequency of access to extension. An enterprise might have a favourable gross margin but farmers will still be reluctant to adopt/ reallocate resources towards it (Ebukiba, 2010).

Optimum farm plans for smallholder farmers can be achieved by employing a linear programming technique. Substantial increase in net farm returns could be realized by proper reorganization of available resources even with the available technology. There are even prospects of higher net farm returns under improved technology with additional resources. Simultaneous provision of credit and adoption of new technology would enhance the income and employment opportunities on small and large farms.

3.3 Analytical Framework

The study employs two frameworks in analyzing the specific data set. The first one is the gross margin analysis (GMA), and the second one is the linear programming model (Onuk et al., 2010); IDEA 2001). The gross margin analysis is the difference between the value of gross output and total variable costs per unit of a resource, usually a hectare of land for a particular enterprise. It is the most common analytical tool used in financial analysis for determining performance of agricultural enterprises and projects (Onuk et. al., 2010; Ebukiba, 2010). The financial performance of enterprises is determined at the market prices by taking account of different input usages and values of outputs. The GMA was chosen because of its simplicity.

To conduct a gross margin analysis for a farm enterprise, a physical budget of the enterprise is transformed into financial terms by attaching costs and prices to each item of the budget.

GM is simple in the sense that it does not consider fixed costs, which are often difficult to compute and allocate to individual enterprises. Following Ebukiba, (2010) GM is specified as follows,

$$\sum_{i=1}^{N} GM_i = \sum P_i * Q_i - \sum_{i=1}^{N} TVC_i$$

Where,

GM = Gross Margin (US$/acre);

TVC_i = Total Variable Cost (US$/acre) of the i^{th} enterprise;

GM is the difference between income and variable costs;

Gross Income (GI) = P_i*Q_i ;

P_i is price per unit of out of a certain enterprise *i*; and

Q_i total quantity produced by the i^{th} enterprise.

Total variable costs (TVC) are the direct costs incurred in producing the output. These costs among others include fertilizers, seed, casual labor, land cultivation and processing (IDEA, 2001). Gross margin is not a decision rule tool because increase in the margin will also results in increase in the relative costs, thus at any particular gross margin there is a corresponding cost structure (Ebukiba, 2010). The results of the gross margin analysis are used in the linear programming model for further analysis. Further economic analyses, for example included estimation of optimal crop mix that will maximize farm income.

With given physical, technical and resource conditions, optimal allocation of resources entails the efficient use of each resource such that the net farm returns are maximized in a year (Cashdollar, 1971). Among the various analytical tools available for allocation of available but limited farm resources, linear programming is one of the most widely and best understood operations research techniques (Ramanna, 1966). It is indeed a powerful technique, which can effectively handle large number of linear constraints and variables or activities simultaneously. Linear programming technique is a useful tool to estimate optimal crop mix of designate form under varied capital and technological environments.

The mathematical formulation of the linear programming (LP) analysis is a sum of a linear function of a number of variables to be maximized subject to a number of constraints in the form of linear equalities and inequalities. In mathematical form, linear programming model can be expressed in the following way;

Maximize

` $$Z_{\max} = \sum_{j=i}^{n} C_j X_j \, ;$$

Subject to;

$$\sum_{j=1}^{n} a_{ij} X_j \le a_i$$ ....land restriction;

$$\sum_{j=1}^{n} b_{ij} X_j \le b_i$$ ....labor restriction;

$$\sum_{j=1}^{n} c_{ij} X_j \le c_i$$ ....manure restriction;

$$\sum_{j=1}^{n} d_{ij} X_j \le d_i$$ ....seed restriction;

$$\sum_{j=1}^{n} e_{ij} X_j \le e_i$$ ....budget restriction, and

$X_j \ge 0$ i.e. The non-negativity condition.

Where;

Z = Objective Function;

X_j = area under jth crop production activity;

C_j = Gross margin per unit of the jth crop activity;

a_{ij}= land coefficient for jth crop;

b_{ij} = labour requirement for jth crop activity;

c_{ij} = manure requirement for jth crop activity;

d_{ij} = seed requirement for jth crop activity;

e_{ij} = budget requirements for the jth crop activity;

a_i =available land in acres;

b_i =human labour available in man-hours;

c_i =available manure in Kg;

d_i =quantity of seed available in Kg;

e_i = amount of money available; and

n =Number of crop production activities.

The LP model starts by assuming an objective function. The objective function consists of the income generating activities which are crop production and or livestock activities. It is assumed that the farmers' objective is to maximize net returns that is a product term of average yield of an enterprise and its unit price to family labor, land, management, and capital invested in the crop enterprises. The linear program is run for maximization of net returns. Linear programming model maximizes income on a representative farm subject to the resource limitations as reflected by resource availabilities on the farms.

In order to run LP model, several basic assumptions are made. For example, besides the general assumptions of linearity, divisibly, non-negativity, additivity, finiteness and certainty, several other potential assumptions are made in developing the model (Varalakshmi, 2007).

In this study, the problem of resource optimization was dealt at the average farm level. Each farm was assumed to be an economic decision making unit. The farm operator was free to make decision regarding the business limited only by legal and contractual arrangements. It was also assumed that each farm was operated with the objective of maximizing net farm returns subject to the described constraints only. Closely related to the above assumptions, the study, to start with, was in static framework. It was assumed that the input and product markets were perfectly competitive, and yield and price expectations of the farmers were single valued.

The model had several restrictions. For example, the row vector in the matrix refers to the constraints in the model. The different types of constraints included in the model were physical resource constraints, product constraints, minimum and maximum area constraints and financial constraints. The model has also resource constraints. There are several resource constraints, for example, land restriction. Besides land, labor is also a limiting factor. Labor could be hired or use of family labor. Farm yard manure and compost were also used as inputs/ factors of production and their limited availability provides limitations to the model.

Finally, the output/product provides limitations to the model. It facilitates the allocation of crop products produced between consumption and marketing. Production inventory at the beginning of the farm operation is supplemented by output from the crop production activities. Family consumption requirement ensures that the minimum requirement of the household is met from the farm itself. The response of the farmers on their minimum requirements of farm products is used to account this constraint.

Further, finances are also a resource limitation imposed due to cash availability. The working capital availability with farmers sometimes may not be sufficient to meet the requirements of different agricultural operations. Nevertheless, it may also limit the scope for adoption of improved production practices. Factors like risk, uncertainties, high input costs, and supervision and marketing problems associated with certain enterprises may prevent the farmers from taking up these enterprises beyond certain limits. While allocating the resources, it becomes all the more important to see that the resources allocated to these enterprises do not go beyond the limits set by the farmers. Hence, maximum area that could be brought under high yielding and more profitable crops was specified based on the responses of the sample farmers.

3.4 Expectations of the Theoretical LP Model

Gross margin analysis is used to give information about the performance of each crop in the LP model. Inputs such as land, labor, capital, and other production costs variables are factored into the model to give total variable cost. Positive margins are expected after less the total variable costs from gross income for chili and other crops. A positive gross margin is expected which implies that the crop is performing well, and can be incorporated into the crop mix on the farm. Average gross margin for chili is expected to be relatively higher than the other major crops grown in the two Districts. However, information from gross margin alone will not help in estimating the optimal crop mix; hence the information is then used in informing linear programming for the estimation of the optimal crop mix.

Linear programming is used to determine the optimal combination of maize, groundnuts, chili and sugar beans to produce and sell to maximise profits. It is every farming household’s goal to maximise profits. In the process of maximizing income, substitution and reallocation of resources will take. There is going to be a substitution of factors of production in favor of chili and increase in overall income of the average farmer in Goromonzi and Marondera Districts and government policy can play a role in favor of increased chili production

3.5 Conclusion

Chapter 3 presented the research methods which were going to be used to achieve my objectives. The first section looked at the conceptual framework. The conceptual framework discussed the conceptualization of the economic relationships in the study. Introduction of a new enterprise affected resource allocation as farmers re-organized resource use to accommodate new enterprise and increase income.

The second section looked at the analytical framework that has been used to estimate optimal crop mix on the average farm. Gross margin is not a decision tool because increase in margin will also results in increase in relative costs, thus at any particular gross margin there is a corresponding cost structure. The gross margin analysis determines the financial performance of the enterprise and it informs linear programming analysis. Linear programming analysis handles large number of variables and constraints simultaneously. the method estimates optimal crop mix under smallholder or large scale farming conditions.

Finally, the last section looked at results expected from the study. It was hypothesized that average gross margin for chili is relatively high compared to other crops, and thus there is going to be substitution of land use in favor of chili. To achieve my objectives, the following chapters will analyze the research data. The research data was collected from a field survey using a questionnaire in Goromonzi and Marondera Districts.

CHAPTER

4 PRELIMINARY ANALYSIS

4.1 Introduction

The main objective of the study is to estimate the optimal crop mix for an average farmer in Goromonzi and Marondera Districts given the introduction of chilies. The chapter starts by providing sampling methods, data collection and data management to produce socio-economic characteristics of farmers in Goromonzi and Marondera Districts. The chapter further looks at the socioeconomic characteristics of smallholder farmers in the communal farming areas of Goromonzi and Marondera Districts where organic chili production is taking place. The chapter further presents the gross margin budgets for major crops grown in the areas.

Finally, the chapter estimates average gross margin budgets for major crops grown in Goromonzi and Marondera Districts where chili production has been introduced by Kaite. The analysis will test the first hypothesis that chili has the highest gross margin relative to other crops grown by farmers. The hypothesis is answered using gross margin created in Excel Program. Gross margin is the difference between gross income and total variable costs of undertaking activities of the enterprise. It is a simple indicator of performance of an enterprise. It does not measure a crop's profitability.

4.2 Sampling Procedure, Data Collection and Data Management

The study was carried out in Goromonzi and Marondera Districts in Zimbabwe's Mashonaland East Province. Goromonzi and Marondera Districts are in agro-ecological region 2b, a semi-intensive farming region with annual rainfall of 750-1000mm. The vegetation is mainly '*mutondo'* woodland on predominantly sandy loam soils of low inherent fertility. Field crops under production are mainly maize, a staple food crop; cow pea; groundnut, sugar beans and the garden crops including, chili, onions, garlic, tomatoes and leafy vegetables. The livestock types within the farming systems are cattle, goats and poultry (sample data).

A sample of 288 farmers took part in the survey on chili production and market access conducted in February, 2010 in Goromonzi Districts and Marondera district. Samples were taken from 68 villages from both districts and it consists of farmers who are affiliated to Fambidzanai Permaculture Centre (FPC) and practice organic farming. Purposive sampling method was employed to capture mainly the characteristics of smallholder farmers in organic farming in the chili producing areas of Goromonzi and Marondera Districts. Of the 288 farmers interviewed, 91 farmers were growing chili. Further to that, 33 farmers took part in the final gross margin analysis. The results are likely to be biased given the circumstances in which the data was collected. Given the conditions, this was the best we could do.

Both primary and secondary data was sought and analyzed through different methods in this study. Socio-economic surveys were conducted using a questionnaire to generate socio-economic data. Informal discussions were also conducted with key informants who had vested interest, knowledge and experience in Chili production to generate both socio-economic data and other information on economic, technical and social aspects of chili system. The key informants included farmers marketing task force, field officers for Fambidzanai and Kaite, contracting buyer for chili and AREX officials.

The farmers' marketing taskforce were asked to provide information on issues of seedlings procurement, organic practices employed and their costs, prices offered by the contractor visa vie their expected price, and challenges they were facing in producing the chili. The field officers of the two organizations working with the farmers were asked to inform on potential markets of chili once certified, and mechanisms that were put in place to help farmers with the certification process. The informal discussions with the informants sought information on current work and future plans on the chili system in the areas.

Secondary data were collected through literature study of various articles, both published and unpublished on chili production, specifically on previous studies from the region and the rest of the world. The literature study sought information from journal articles and other working papers on history and distribution of chili production in the country and the rest of the world; and implications of introducing a commercial crop with special production characteristics to the smallholder farming systems.

A household questionnaire was designed for this study, see Appendix C. It explored information on socio-economic characteristics of the households, their farming systems, land ownership and utilization patterns, farm resource endowments, farmer perceptions on chili production and farm management data among many other things. A total of 288 households were interviewed. Twelve enumerators, in addition to the researcher, were engaged and trained before conducting the survey. The enumerators included farmers, field officers, program officer and monitoring officers from Fambidzanai. The training was meant to familiarize them with different sections of the questionnaire. The team participated in pre-testing the questionnaire in which each enumerator interviewed two farmers and a total of 26 households were pre-tested. The actual questionnaire administration process took one week and a total of 288 questionnaires were completed. The information collected through the questionnaire was further validated by focus group discussions.

Five focus group discussions (FDG) were conducted with a group consisting of at least 12 chili farmers to get a common position and gain a clear understanding of socio-economic issues affecting chili production and marketing. The FDG were conducted soon after the household questionnaire administration was completed to ensure that individual farmer responses were not influenced by outcomes of the FDG.

The farming community of the study area was found to be following diversified production pattern probably to minimize the risk of loss due to failure of crops. The details on the existing cropping pattern, cropping intensity and net farm returns were presented in Table 4.1 below. The existing production program of the farmers in 2010 included maize, ground nuts and sugar beans. Maize is the staple crop of the farmers and it occupied 1.87 acres of the land owned. Oil seed crop such as ground nuts occupied 0.48 acres of the land. Fallow land constituted more than half of the land, 3.89 acres.

Table 4.1: Existing Cropping Pattern

Crop	**Average Area (acres)**
Maize	1.87
Ground nuts	0.48
Sugar beans	0.26
Fallow land	3.89
Total land	6.5

Source: Data

Resource use patterns for each enterprise in the existing production program was worked out for each farm by calculating cost of different items of inputs. In this analysis, only variable costs were taken into consideration for the purpose of calculating gross margin budgets. Total cost of production is therefore referred to as total variable costs. Variable costs mainly comprised cost of labor, cost of farm yard manure and liquid manure, seed cost and other costs.

4.3 The Economics of Chili Production in Goromonzi and Marondera Districts

Smallholder farmers in chili growing areas can be categorized into two. There are farmers who are in chilli growing areas practicing organic farming but have nothing to do with the chili crop. These farmers are referred to as non-chili farmers in this study. The other category comprises chili farmers; those farmers who have chili on their farms and are harvesting and or processing chili for marketing to contracting private organisation Kaite. Table 4.2 below shows distribution of sampled households across the activities being undertaken on chili by district.

Table 4.2 Sample Distribution across Farmers' Categories

	Chili farmers		**Non chili farmers**	
	frequency	Percentage (%)	Frequency	Percentage (%)
Marondera	50	18	88	30
Goromonzi	41	14	109	38
Total	91	32	197	68

Source: Data

Chili farmers constitute 32% of the sampled farmers in both districts of the farmers practising organic farming. More farmers are still to adopt chili into their farming systems as indicated by low percentages in both districts.

The Table 4.3 below describes area of non-chili crops in farmers producing chili and those that are not. There is no significant difference in area under field crops in both types of farmers such as maize, groundnuts, sugar beans, and round nuts. For chili farmers, chili constitutes 6.4% of the total area under production inclusive of field crops. However, field crops such as maize (50%), groundnuts (12.8%), and sugar beans (7.0%) have higher percentages.

Table 4.3 Area under Chili and other Crops

Crop (Average acres)	**Chili farmers (Average Acres)**	**Non-chili farmers (Average Acres)**
Chili	0.24	0
Maize	1.87	1.60
Ground nuts	0.48	0.38
Sugar beans	0.26	0.19

Source: Data

Chili Production is intensively produced in some areas, for example, in the sampled districts, 91 farmers out of 288 were growing chili and of those that were growing chili, their plant population ranged from 100 to 1500 plants/ha with an average of 405 plants/ha and standard deviation of 286.4 plants/ha. The contract for chili is a 0.25 acres with plant population of 425 chili plants. Table 4.4 below shows that farmers had area which ranged from 0.06 acres to 0.88 acres with a mean of 0.24 acres and a standard deviation of 0.16652 acres. Farmers below mean, less half standard deviation are classified as low producers and those above the mean plus half standard deviation are the high producers. In terms of area under chili, low producers are below 0.16 acres and high producers are above 0.32 acres. In terms of chili population, high producers have chili plants greater than 548 plants/ acre and low producers have chili plants below 262/acre.

Table 4.4 Descriptive Statistics of Chili Producers.

	Low producers (<262 plants)	**High producers (>548 plants)**
Number of farmers	34	14
Average area (Acres)	0.11	0.56
Average Chili population	187	957
Min area	0.06	0.35
Max area	0.15	0.88
Std deviation	0.2680	0.17629

Source: Data

There are several reasons why some farmers decide to produce chili and why some decide not to produce chili. Table 4.5 below describes participation in chili production with respect to demographic data. Chili farmers contribute a third of the sample population. Marondera and Goromonzi Districts contribute about 18% and 15% of national output respectively. About 24% of the samples are female farmers who are in chili production. About 90% of the farmers are married, however only 30% of them are involved in chili farming.

Table 4.5 Level of Participation in Chilies with Respect to Demography

Household head characteristics	**Level of participation**		**Pearson's Chi-square Test, X^2**
	Chili farmers	**Non chili farmers**	
District			**0.187**
Marondera	**50 (18)**	**86(31)**	
Goromonzi	**41(15)**	**101(36)**	
Gender			0.196
Male	24(9)	37(13)	
Female	67(24)	150(54)	
Total	**91**	**187**	
Age			**0.445**
Total	**91**	**187**	
Marital status			0.551
Married	83(30)	166(60)	
Not married	8(3)	21(7)	
Total		**187**	

** = Significant at 95% level. Figures in parenthesis are percentages.
Source: Data.

Besides physical and demographic characteristics, socio-economic characteristics also determine participation in chili production. The table 4.6 below shows that more than 50% of the farmers went as far as high school; however there is no significant relationship between education level and participation in chili farming. A larger proportion of chili farmers have secondary level education. 86% of the farmers rely on farming for their source of income and Pearson's Chi-square test is significant at 95% indicating that relation exists between education level and whether a farmer is a producer of chili or not.

Table 4.6 Level of Participation with Respect to Social Characteristics

Household head characteristics	**Level of participation in chili system**		**Total, N (%)**	**Pearson's Chi-square Test, X^2**
	Chili producers	***Non chili producers***		
No. of years spent in school	**91**	**187**	**100**	0.889
Source of income				0.012**
	84	**178**	**100**	
Knowledge of organic farming				0.844
	91	**187**	**100**	

(**= Significant at 95% level; * = significant at 90% level)

Source: Data

Farm resource endowments also determine participation in chili production. Table 4.7 below shows the averages of economic resources in farming households in relation to their participation in chili production. The Pearson's Chi-square test of association suggests existence, at the 95% level of significance, of a relationship between cattle ownership, of hoes and scotch carts, and a household's production status. However, no significant relationship exists between ownership of goats and ploughs in relation to chili production status.

Table 4.7 Level of Participation with Respect to Economic Resources

Household head characteristics	**Level of participation in chili system**		**Pearson's Chi-square Test, X^2**
	CHILI producers	***Non chili producers***	
Total land size(acres)	6.7	6.8	0.512
Livestock holding			
Cattle	5	5	0.035**
Economic resources			
Plough	1	1	0.826
Hoes	7	6	0.044**
Wheelbarrow	**1**	1	0.083*
Shovels	**2**	1	0.066*
Scotch carts	1	0	0.038**

(***, **,* = Significant at 99%, 95%, 90% level)
Source: Data

The other factor that determines chili participation is labor. The number of people able to work in the fields ranges from 1 to 10 with an average of 4 people per household of 7 members. There is no difference in the number of people being able to work in the fields between chili and non-chili farmers. More than 50% of the farmers use solely family labor in their production with only 12% being able to hire 2 people mainly during weeding times. Daily rates vary widely from $1 to $5 per person depending on amount of weeding to be done. However, most chili farmers pay $3 per person per day with a standard deviation 1.038.

Farming experience also determines participation in chili production. Chili farmers have farming experience of more than 22 years and have a minimum of 4 years doing organic agriculture which is essential in chili production. Whereas non chili farmers have been farming for more than 25 years, however they have similar experience in organic farming practices. Finally, membership to farming organizations also determines participation in chili production. About 46%, 22%, 11% and 13% of chili producing farmers belong to farming organization such as FPC and SOFA, GOFA and local groups respectively.

4.4 Gross Margin Budget Analysis for Chili and other Major Crops

The gross margin analysis is the difference between the value of gross output and total variable costs per unit of a resource such an acre of land for a particular enterprise. It is the most common analytical tool used in financial analysis for determining performance of agricultural enterprises and projects. The financial performance of the enterprise is determined at the market prices by taking account of different input usages and values of outputs. To conduct a gross margin analysis for a farm enterprise, a physical budget of the enterprise is transformed into financial terms by attaching costs and prices to each item of the budget. Indications of costs and prices used in this analysis were from the household survey conducted in the study areas. This study focuses on farmers who produced chili and other crops such as ground nuts, maize and sugar beans.

To conduct a gross margin budget analysis, several assumptions were made. For example, family labor is valued at the same cost as hired labor such as the opportunity cost of hiring labor to the other farmers which is the village wage rate. The outputs were valued at market prices observed in both districts at the time of conducting the survey. Finally, private costs and benefits accruing directly to the farmer and not social costs were considered in this analysis. The Table 4.8 below shows the various gross margin budgets for the major crops grown in the two Districts.

Table 4.8 Whole Farm Gross Margin Budget

	CHILI	SUGAR BEANS	GROUND NUTS	MAIZE
YIELD LEVEL (kg/ACRE)	190.07	428.4	481	833
PRICE ($KG)	3	1	1	0.33
GROSS INCOME	**570.21**	**428.40**	**481.00**	**274.89**
TOTAL VARIABLE COSTS ($/acre)	**190.03**	**247.50**	**131.64**	**175.27**
GROSS MARGIN($/acre)	**380.09**	**180.91**	**349.36**	**53.81**
RETURN/$VC	2.00	0.73	2.65	0.31
VARIABLE COSTS				
1.Seed	41.66	63.00	36.50	20.83
2. Land prep	17.20	35.15	17.20	16.67
3. Fertilizer	53.39	67.70	29.30	51.25
4. Insecticide				11.67
5. Packaging materials	2.30	15.00	4.00	17.50
6. Transport	3.00	29.00	2.00	24.50
7. Labour	68.75	33.50	40.06	30.00
8. Miscellaneous	3.73	4.15	2.58	2.85
TVC	**190.03**	**247.50**	**131.64**	**175.27**

Source: Data

Chili has the highest gross margin followed by ground nuts, sugar beans and maize respectively. The average gross margin budget for an average farmer in the two Districts is shown in the Table 4.9 below. The first hypothesis of the study is to test that chili's gross margin budget is relatively higher relative to other crops. The gross margin for the crops are about US$380, US$350, US$181 and US$54 for chili, ground nuts, sugar beans and maize respectively. Ground nuts have the highest return per gross margin followed by chili. However farmers have large areas under chili because of the ready market provided by the contract compared to ground nuts which have to be sold on a competitive market. The Table 4.9 below shows that all the crops have positive gross margins with chili having the highest followed by groundnuts, sugar beans and lastly maize.

Table 4.9: Financial Performance Indicator for Chili, Ground nuts and Sugar Beans

Indicator	**Chili**	**Groundnuts**	**Sugar beans**	**Maize**
Financial performance				
TVC	190.12	131.65	247.49	175.27
Gross income (GI)	570.21	481.00	428.41	229.08
Gross margin (GM)	380.17	349.53	180.92	53.81
GM/TVC	2.0	2.65	0.73	0.31

Source: Data

4.5 Conclusion

Based on the results outlined in this chapter, 32% of the farmers are involved in chili production while the greater proportion (68%) is non-chili producers. According to this survey, farming is the major source of income and there is a 95% level of significance between major source of income and whether a farmer produces chili or not. Also farm resource endowments and livestock numbers contributes to whether farmer participates in chili production or not.

Household size, farming experience and cattle are influencial in determing performance of chili farmers in terms of yield and gross margins. These social characteristics shapes the perfomace of a farmer. Thus if a household has a family size of 6 and above, that means more labor is available for the labor intensive crop. Farming experience and total land also affected yield of chili.

Gross margin budget analysis revealed that chili had the highest average gross margin of US$380.17 with maize having the least of US$53.81. Further gross margin analysis showed that chili had second highest return per variable cost of 2 after ground nuts with return per dollar of 2.65. However, farmers had larger areas under chili because of the ready market as compared to ground nuts. Gross margins are useful for farm planning and making comparisons of enterprises on the same farm. However, gross margin analysis does not provide optimum crop mix; hence further economic analysis is required with the use of linear programming analysis. The next chapter will focus of linear programming analysis in trying to estimate the optimum crop mix of farm using information from the gross margin budgets.

CHAPTER

5 LINEAR PROGRAMMING ANALYSIS

5.1 Introduction

The objective of this chapter is to estimate the optimal crop mix given an average communal farm. Chapter 4 estimated the average communal farm's gross margin budget using surveyed data. The chapter estimates the optimum crop mix for an average farm. The second section of the chapter specifies the linear programming model that will be used in the analysis. There are several assumptions and constraints that will be specified in the model. The objective function of the model is to maximize gross return subject to constraints.

The third section of the chapter estimates the specified linear programming model. There are several problems that are encountered when running a linear programming model. For example, unbounded solutions or infeasible solutions might be encountered. These may indicate a mispecified constraint. Section four discusses the results. Finally, sensitivity analysis is carried out. Sensitivity analysis shows that any percentage change in a binding constraint will have an effect on the optimal crop mix that will result.

5.2 Model Specification

Chili is grown over 18 months and harvested for 12 months after planting, thus a chili cropland is out of circulation for two seasons. Basic assumptions still apply for production technology options for smallholder farmers in Marondera and Goromonzi which are:

(i) 7 person household with 6 labour units, such that family labor = labor units * monthly days* production season.

(ii) Family consumption requirement for maize per year = individual consumption requirement per year* family size.

(iii) Farm activities: mixed farming enterprise; chili, maize, sugar beans, ground nuts,

(iv) Complete markets exist for all crops and food stuffs.

Objective function

Specifications of the objective function of the household;

Max $Z = \sum C_j X_j$; subject to constraints;

Where; Z is household income;

C_j is income from individual enterprises; and

X_j are crop enterprises, chili, sugar beans, ground nuts and maize respectively.

Constraints of the model

(i) Land constraint is $\sum X_i \leq a$;

Where X_i is area under chili, maize, sugar beans and ground nuts respectively and *a* is total land area;

(ii) Labor $\sum X_i * D_i \leq q + w$;

X is area under various crops;

D is labor days for each crop;

q is family labor; and

w is hired labor.

(iii) Capital $\sum X_i * V_i + qmb * pmb \leq 1000 + lt * wn - \ln * wt$;

Where,

X is area under various crops;

V is variable costs of crop;

qmb is quantity of maize bought;

pmb is buying price of maize;

lt is labor out;

wn is wage in;

ln is hired laobr; and

wt is wage out.

(iv) Labor balance $\sum X_i * D_i + lt \leq fb + \ln$;

Where *fb* is family labor;

(v) [maizebal] Ym*Am+qmb-qms-Qmc>=0;

(vi) [sugarbeanbal] Ys*As-qss-qsc>=0;

(vii) [chilibal] $Yc_1*Ac_1+Yc_2*Ac_2$-qcs>=0; and

(viii) [groundnutbal] Yg*Ag-qgs-qgc>=0.

5.3 Linear Programming Models

Linear programming model is run in a computer program called LINGO. The first thing is to specify the assumptions that will guide the program. The next step is to specify the objective function and define the terms/ variables that constitute it. After defining the objective function, the next step is to identify and specify the constraints to which the function is subjected to. The last section of the model is the parameters that will guide the model. The Table 5.1 below summarizes parameters that were used in S1 model/ introduction of chili to farming system.

Table 5.1 Summary of Parameters

Enterprises	Prices (US$)	Variable costs (US$)	Yield (kg/acre)
Maize	0.3	175	833
Maize buying	0.4	-	-
Chili 1	3	190	190
Chili 2	3	50	200
Sugar beans	1	247	428
Ground nuts	1	132	481

Source: Data

Several runs of the model have to be done before a solution is found. For example, one might encounter an unbounded solution, meaning that model will not have a solution. The model is not bounded and one of the constraints has to be redefined. Also, problems of infinite solutions were also encountered

5.4 Results from Linear Programming Models

The main objective of linear programming is to test the null hypothesis that there is going to be a substitution of factors of production in favor of chili and increase in overall income of the average farmer in Goromonzi and Marondera Districts. The baseline model/S0 is the model that is run without chili production. Results from the analysis showed that, farmers can optimize income by growing 0 acres, 5.7 acres and 0.3acres of maize, ground nuts and sugar beans respectively. Moreover, farmers can get a net income of US$2912.33.

Further analysis, with the introduction of chili revealed that farmers can achieve net income of US$3082.00 on 5.5 acres, 0 acre, 0.2 acres and 0.3 acres of chili, maize, ground nuts and sugar beans respectively as shown in model S1. The results show that there is a shift in factors of production into chili production and an overall net increase in returns is realized. The results of cropping pattern under model S0 and S1 are presented in Table 5.2 below.

Table 5.2 Summary of Results

Crop	**Baseline (S0)**	**Model 1(S1)**
	Area (acres)	**Area (acres)**
Chili	-	5.5
Maize	0	0
Ground nuts	5.7	0.2
Sugar beans	0.3	0.3
Total	6.0	6.0
Net returns (US$)	2912.33	3082.00
Land	0	0
Labor	0	0
Capital	1164.00	845.00

Source: Data

S1 is the optimum crop mix and was developed at the existing level of resources with no labor market and without borrowing. S0 is the baseline model which was developed without chili production. Cash availability was restricted to owned funds only. The purpose of S0 model was to explore the possibilities for reorganizing the farm resources through planning and optimize crop mix.

S1 model estimates optimal crop mix given the introduction of chili. The optimum model S1 suggested reducing the area under groundnuts from 5.7 acres in the S0 model to 0.2 acres in S1 and maize which was eliminated in both models. Maize was not a profitable enterprise, thus household consumption was met through buying. However area under chili increased from 0 and 5.5 acres in the S1model. Area under sugar beans remained the same. The resource optimization and introduction of chili led to a 6 percent increase in net returns. There was a budget surplus in both models meaning that capital was not a constraint. However land and labor were limiting, with farmers willing to pay US$69 and US$100 for an acre of land brought into production in S0 and S1 model respectively. Sensitivity analysis was carried out to show the effects of a percentage change in a binding constraint on the optimal crop mix.

5.5 Sensitivity Analysis

Sensitivity analysis was carried on land and labor which were the most limiting factors in the optimal linear programming model. This section also presents the shadow prices/ dual prices of land and labor in different simulations. Shadow prices refer to marginal value products of resources. They indicate the quantum of change in the net farm returns due to a unit change of that particular resource ceteris paribus. They are of interest to the decision makers (farmers) and planners because they indicate most profitable resources to alter and also the maximum amount of each resource that can be used in a particular production process.

The shadow prices with a positive sign mean that a unit increase in the quantity of resources used would increase the objective function by the amount shown. Shadow prices/ dual prices are zero when a resource is not completely utilized because there is no return added for the marginal use of resource, if all other conditions remaining the same. However, the marginal value products (MVPs) of resource change if one or more other conditions change. The comparison of MVPs of resources (Shadow prices) with their factor cost would provide useful information for making proper resource adjustment and decisions.

The sensitivity analysis was carried out at 5 % and 10 % changes. Table 5.3 below shows effects of a percentage change in land.

Table 5.3 Percentage Change in Land

Crop	**Model S1**	**Model S2a**	**Model S2b**
	Area (acres)	**5% change**	**10% change**
Chili	5.5	5.8	6.1
Maize	0	0	0
Ground nuts	0.2	0.2	0.2
Sugar beans	0.3	0.3	0.3
Net returns (US$)	3082.00	3112.67	3142.67
Land	0	0	0
Labor	0	0	0
Capital	845.00	704.00	563.30

Source: Data

Percentage change in labor constraint resulted in overall increase in net return and a shift in land resource to chili production. Ground nuts, sugar beans and maize areas remained the same both at 5 % and 10 % increase in land available to the farmer. The shadow prices of land and labor remained unchanged at US$100 and US$2 respectively.

Further sensitivity analysis was carried out for labor to determine the effect of a percentage change in labor resource. The results of the sensitivity analysis showed overall decrease in the net return as results of increase in the wage rate for hiring labor that was meant to attract more labor resources. There was no shift in resources from one crop to the other. However capital decrease as wage rate was increased. The Table 5.4 below shows the results of the analysis.

Table 5.4 Percentage Change in Labor

Crop	**Model S1**	**Model S3a**	**Model S3b**
	Area (acres)	**5% change**	**10% change**
Chili	5.5	5.5	5.5
Maize	0	0	0
Ground nuts	0.2	0.2	0.2
Sugar beans	0.3	0.3	0.3
Net returns (US$)	3082.00	2998.00	2913.34
Land	0	0	0
Labor	0	0	0
Capital	845.00	760	676

Source: Data

5.6 Summary

The objective of this chapter was to estimate the optimal crop mix given an average communal farm. The chapter estimates the optimum crop mix for an average farm. The second section of the chapter specified the linear programming model that was used in the analysis. There are several assumptions and constraints that were specified in the model. For example prices of the outputs were the price used for selling at the time of the conducting the survey.

The third section of the chapter estimated the specified linear programming model. Unbounded solutions or infeasible solutions were encountered in running the model and some of the constraints were redefined. Section four discussed the results. The optimum crop is 0.2

acres, 0.3 acres, 5.5 acres and 0 acres of ground nuts, sugar beans, chili and maize respectively. The optimal crop gross return is US$3082.

Finally, sensitivity analysis was carried out. Sensitivity analysis showed that a percentage increase in land affected the optimal crop mix of the average farm. Land under chili increased both at 5% and 10 % change resulting in the overall increase in gross return. Areas under the other crops remained the same. Further sensitivity analysis showed that a percentage change in labor resulted in a decrease in the gross return. However there were no factor movements both at 5 % and 10 % change.

CHAPTER

6 DISCUSSION OF RESULTS AND POLICY RECOMMENDATIONS

6.1 Introduction

The main objective of this chapter is to discuss the results that have been found in the study and inform policy. It tests the hypothesis that government policy can play a role in favor of increased chili production. Chapter 5 estimated the optimal crop mix for an average farm and carried out sensitivity analysis. The second section of the chapter discusses preliminary results. The preliminary analysis focuses on sampling procedure, data collection and data management. It further discusses the economics of chili production and farm gross margin analysis of chili and other crops.

The third section discusses the estimation of the optimal crop mix using linear programming analysis. Linear programming analysis is specified and run. Results of the analysis are presented and sensitivity analysis is done to determine the effects of change in a resource on the optimal crop mix. Finally, the chapter discusses the policy implications and recommendations.

6.2 Preliminary Analysis

General household characterization showed that 32% of the farmers' are already producing chili whereas the greater proportion is non-chili producers. According to this survey, farming is the major source of income and there is a 95% level of significance between major source of income and whether a farmer produces chili or not. With respect to literacy rate, it was noted that the majority of the farmers in the study area were literate. Literacy level of sample farmers ranged from primary education to tertiary. The average farm size in the study area was 6.0 acres. Further the pattern of land holding revealed that farmers with large pieces of land had more area under chili.

Also farm resource endowments and livestock numbers contributes to whether farmer participates in chili production or not. Extension contact, gender and membership to farming organization were found to be significant in shaping households decisions of whether to produce chili or not. Most chili farmers belong to FPC (46%) and SOFA (22%), GOFA (11%) and local groups (13%). Belonging to farmer groups and having greater frequency of extension contact has a bearing on the intensity of chili produced. More than 50% of the farmers use solely family labor in their production with only 12% being able to hire 2 people mainly during weeding times.

Gross margin budget analysis revealed that chili had the highest average gross margin of US$380.17 with maize having the least of US$53.81. However, farmers had larger areas under chili because of the ready market as compared to ground nuts. Information from the gross margin budgets was used for further analysis in estimating the optimal crop mix given the introduction of chili.

6.3 Linear Programming Analysis

Chapter 5 estimated the optimal crop mix given an average communal farm. The optimum crop mix is 0.2 acres, 0.3 acres, 5.5 acres and 0 acres of ground nuts, sugar beans, chili and maize respectively with gross return of US$3082. Sensitivity analysis showed that a percentage increase in land affected the optimal crop mix of the average farm. Land under chili increased both at 5% and 10 % change resulting in the overall increase in gross return. Areas under the other crops remained the same. Further sensitivity analysis showed that a percentage change in labor resulted in a decrease in the gross return. However there were no factor movements both at 5 % and 10 % change. With insights from sensitivity analysis, the next section discusses the policy recommendations that will favor increase in chili production.

6.4 Policy Recommendations

For farmers to increase their household income, they have to improve in their chili performance through belonging to farmer organisations and receiving information from extension agents in their areas. Farmers have to improve in their marketing practices by out sourcing better markets for maize and ground nuts as well as sugar beans. Further to that, an average communal farmer can increase his/her production levels through increased use of better inputs such as organic fertilisers and composts. Increase in supply of crops will lure large buyers to the districts and creates certainty of a continuous supply and will grant them more bargaining power in negotiating contracts and better markets.

Farmers often lack financial resources to buy equipment such as cement for building liquid manure pits and setting up small irrigation facilities that are necessary to increase production performance. Provision of production inputs increase production and adoption of a certain crop. Contracting companies that offer production and marketing services are highly recommended for all the crops.

For farmers to meet the market requirements, they need information about the quality and quantity that the market demands. They need information about good production and curing practices. Farmers who were not trained by Fambidzanai and Kaite staff did not have this information which means there is need for further extension services to reach out to those who were not part of this training. Information on prices is also required. Market prices change during the course of the marketing season; therefore farmers need to be provided with this information so that they know the marketing strategies to employ.

Policy makers should advocate for an enabling environment for farmers to operate in to achieve an optimal crop mix. For example, support services such as extension, provision of market information and improvement of road and communication infrastructure could ensure a smooth movement of products and information. Formation of marketing groups/associations by farmers to reduce operating costs through exploitation of economies of scale should be encouraged and supported. Farmer groups reduce transaction costs. These can be extension groups where farmers can be trained and share information based on their different experiences. They can also form marketing groups where they sell produce collectively and deal with the buyer as a group. For large buyers, it is easier for them to deal with a group than too many individuals.

Organisations that represent smallholder farmers should be effective in delivering their services. They should also provide better education and training in negotiating of contracts such that farmers will not be short changed by buyers. Also market prices for maize should encourage its production such that farmers' food security will not be compromised. Finally, there is need for increase in extension services by reducing extension farmer ratio and conducting in-situ training to increase production performances of farmers as this translate to increased incomes. NGOs should also assist farmers in setting up marketing task force that would help farmers in negotiating transactions and sourcing better paying markets.

CHAPTER

7 SUMMARY AND CONCLUSIONS

7.1 Summary

The findings from the analytical chapters are summarized and presented in this section in accordance to the objectives of the study. The general objective of the study was to estimate the optimal enterprise mix for an average farmer in Goromonzi and Marondera Districts given the introduction of chili. The first objective was to estimate average gross margin budgets for major crops grown in Goromonzi and Marondera Districts. The average gross margin then informs linear programming to estimate optimal crop mix for the average farmer for Goromonzi and Marondera. Finally the last objective was to make policy recommendations about introduction of chili in the production systems of Goromonzi and Marondera Districts.

The study was carried out in Goromonzi and Marondera districts. From the two districts, farmers who were affiliated to Fambidzanai permaculture centre and were practicing organic agriculture were selected for the detailed study. A total of 288 farmers took part in the study. The required data were collected in the structured schedule developed for the purpose through the personal interviews from the respondents. The data pertain to the agricultural year 2009-2010.

General household characterization indicated that the average family size of the sample farmers in study area was 6 and was directly related to area under chili. Literacy level of sample farmers ranged from primary education to tertiary. It was observed that the average farm size in the study area was 6 acres. Farm resource endowments and livestock numbers contributed to whether farmer participates in chili production or not. Extension contact, gender and membership to farming organization were found to be significant in shaping households decisions of whether to produce chili or not.

Belonging to farmer groups and having greater frequency of extension contact has a bearing on the intensity of chili produced. More than 50% of the farmers use solely family labor in their production with only 12% being able to hire 2 people mainly during weeding times. Most chili farmers paid daily wage rates of $3 per person. Most farmers had farming experience of more than 22 years and have a minimum of 4 years doing organic agriculture which is essential in chili production.

Farm gross margin analysis was used to estimate the average gross margins for major crops grown in the areas including chili. Information obtained from the gross margins was then used for further analysis in linear programming. Gross margin analysis showed that chili had second highest return per variable cost of 2 after ground nuts. However, farmers had larger areas under chili because of the ready market as compared to ground nuts. Gross margin analysis revealed highest gross margin from chili followed by groundnuts. The average gross margins for the major crops were US$380.07; US$349.36; US$180.91; and US$53.81 for chili, ground nuts, sugar beans and maize respectively. The optimum crop mix is 0.2 acres, 0.3 acres, 5.5 acres and 0 acres of ground nuts, sugar beans, chili and maize respectively. The optimal crop gross return is US$3082.

7.2 Conclusions

Household size, farming experience and cattle are influencial in determing performance of chili farmers in terms of yield and gross margins. These social characteristics shapes the perfomace of a farmer. Thus if a household has a family size of 6 and above, that means more labor is available for the labor intensive crop. Farming experience and total land also affected yield of chili.

Gross margin budget analysis revealed that chili had the highest average gross margin of US$380.17 with maize having the least of US$53.81. Further gross margin analysis showed that chili had second highest return per variable cost of 2 after ground nuts with return per dollar of 2.65. However, farmers had larger areas under chili because of the ready market as compared to ground nuts. Gross margins are useful for farm planning and making comparisons of enterprises on the same farm. However, gross margin analysis does not provide optimum crop mix. The optimum crop mix is 0.2 acres, 0.3 acres, 5.5 acres and 0 acres of ground nuts, sugar beans, chili and maize respectively. The optimal crop gross return is US$3082.

Sensitivity analysis showed that a percentage increase in land affected the optimal crop mix of the average farm. Land under chili increased both at 5% and 10 % change resulting in the overall increase in gross return. Areas under the other crops remained the same. Further sensitivity analysis showed that a percentage change in labor resulted in a decrease in the gross return. However there were no factor movements both at 5 % and 10 % change.

The results from the study recommends that farmers need to belong to farmer organisations and receive regular information from extension agents in their areas for them to improve in their chili performance. Farmers have to improve in their marketing practices by out sourcing better markets for maize and ground nuts as well as sugar beans. In order for smallholder farmers to realise higher income levels and to spread production costs, they need to increase their production levels through increasing their production performances. Bringing together supply of crops will lure large buyers to the districts and creates certainty of a continuous supply and will grant them more bargaining power in negotiating contracts and better markets.

Producer price of maize is very low such that farmers are better off buying maize to meet consumption requirements than producing. Thus there is need for a policy change that will favour production of maize. Farmers require information about the quality and quantity that the market demands. Information on prices is also required. Market prices change during the course of the marketing season; therefore farmers need to be provided with this information so that they know the marketing strategies to employ. Farmers can form groups in order to reduce transaction costs. These can be extension groups where they can be trained and share information based on their different experiences.

Policy makers should advocate for an enabling environment for farmers to operate in to achieve an optimal crop mix. Support services such as extension, provision of market information and improvement of road and communication infrastructure could ensure a smooth movement of products and information. Formation of marketing groups/associations by farmers to reduce operating costs through exploitation of economies of scale should be encouraged and supported. There is need to reduce extension farmer ratio and on-going in-situ training to increase production performances of farmers as this translate to increased incomes. NGOs should also assist farmers in setting up marketing task force that would help farmers in negotiating transactions and sourcing better paying markets.

7.3 Limitations of the Study and Areas of Further Research

The study was not thorough in its instigation of the economics of chili production and income among smallholder farmers as it concentrated on only two districts in the whole country that are being assisted by Fambidzanai permaculture centre and are marketing their chili to a contracting company called Kaite, eliminating the possibility of including farmers in other districts. There is need, in future studies, to include other areas where chili is grown so that findings can be generalized across the whole country.

This study neglected other tangible and intangible social and environmental costs and benefits which may have significant implications in explaining the dynamics in chili system. The analysis of financial performance of chili was not comprehensively done due to this negligence and it is imperative that future studies do thorough cost-benefit analysis (CBA) and mathematical programming, which can reveal income and welfare implications of introducing chili among smallholder farmers.

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APPENDIX A GROSS MARGIN BUDGETS

A1 GROSS MARGIN RESULTS BUDGET FOR DRYLAND MAIZE 07/01/2011

	price (US$)	quantity	units	income/cost
YIELD LEVEL (T/ACRE)		0.833	tons	
BLEND SELLING PRICE ($/T)	275	1	tons	275.00
GROSS INCOME				**229.08**
TOTAL VARIABLE COSTS ($/ACRE)				**175.27**
GROSS MARGIN($/acre)				**53.81**
GROSS MARGIN ($/$100 VC)				10.76
GROSS MARGIN PER LABOUR DAY (6hrs)				1.00
No. of labour hours/acre				112.00
VARIABLE COSTS			$/acre	
A. PRIOR TO HARVESTING				
1.Seed		10.42	kg/acre	20.83
2. Land prep				16.67
3. Fertilzer (ex-factory)				0.00
a. Maize fert (D)				37.50
b. Amonium nitrate				13.75
c. Transport				4.50
4. Insecticide Dipterex 2.5%		1.67	kg/acre	11.67
5. Miscellaneous		2	%	2.10
B. HARVESTING & MARKETING				
1. Packaging materials				
a. Bags				16.67
b. Twine		0.09	kg/ton	0.83
2. Transport off farm				20.00
3. Miscellaneous		2	%	0.75
Labour				30.00
TVC				**175.27**

Assumptions

Compund D	kg	62.50
Amonium nitrate	kg	20.83
Lime	kg	104.17
Total	ton	187.50

Gazzetted US$ 265 minimum parity price/tonne or US$6.20/ bucket

A2 GROSS MARGIN RESULTS BUDGET FOR CHILI **07/01/2011**

	price (US$)	quantity	units	income/cost
YIELD LEVEL (kg/ACRE)		190.07	kg	
SELLING PRICE ($/kg)	3		$	
GROSS INCOME				**570.21**
TOTAL VARIABLE COSTS ($/acre)				**190.03**
GROSS MARGIN($/acre)				**380.18**
Return/$VC				**2.00**
VARIABLE COSTS			$/acre	
1.Seed	0.01	4166	kg/acre	41.66
2. Land prep				17.20
3 a. Fertilzer (farm yard manure)				29.50
3b.Liquid manure				23.89
4. Labor (Weeding and harvesting)				68.75
5. Transport				3.00
6. Packaging materials				2.30
7. Miscellaneous		2	%	3.73
TVC				**190.03**

Assumptions

gazetted price is US$3/kg

buying place is walking distance from the farmer's plot, less transport costs

contract farming which provides seeds, extension services and guaranteed market.

A3 GROSS MARGIN RESULTS BUDGET FOR GROUND NUTS **07/01/2011**

	price (US$)	quantity	units	income/cost
YIELD LEVEL (kg/ACRE)		481	kg	
SELLING PRICE ($/kg)	1		$	
GROSS INCOME				**481.00**
TOTAL VARIABLE COSTS ($/acre)				**131.64**
GROSS MARGIN($/acre)				**349.36**
Return/$VC				**2.65**
VARIABLE COSTS			$/acre	
1.Seed	1.46	25	kg/acre	36.50
2. Land prep				17.20
3 Fertilzer (farm yard manure)				29.30
4. Labor (Weeding and harvesting)				40.06
5. Transport				2.00
6. Packaging materials				4.00
7. Miscellaneous		2	%	2.58
TVC				**131.64**

A4 GROSS MARGIN RESULTS BUDGET FOR SUGAR BEANS **07/01/2011**

	price (US$)	quantity	units	income/cost
YIELD LEVEL (kg/ACRE)		428.4	kg	
SELLING PRICE ($/kg)	1		$	
GROSS INCOME				**428.41**
TOTAL VARIABLE COSTS ($/acre)				**247.50**
GROSS MARGIN($/acre)				**180.91**
Return/$VC				**0.73**
VARIABLE COSTS			$/acre	
1.Seed	1.5	42	kg/acre	63.00
2. Land prep				35.15
3 Fertilzer (farm yard manure)				32.00
Compound D				35.70
4. Labor (Weeding and harvesting)				33.50
5. Transport				29.00
6. Packaging materials				15.00
7. Miscellaneous		2	%	4.15
TVC				**247.50**

APPENDIX B LINEAR PROGRAMMING ANALYSIS

Appendix B1 Linear Programming results: S0 model/ no chili production

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CHILI PRODUCTION SYSTEM
- Chili is grown over 18 months and harvested for 12 months after planting
- Thus a chili cropland is out of circulation for two seasons
- Land is not scarce but labor is scarce

SCENARIO ANALYSIS - SMALLHOLDER FARMER HAS OPTION
(A) TO ENGAGE IN A MARKETING CONTRACT
(B) TO ENGAGE IN A PRODUCTION AND MARKETING CONTRACT

Basic assumptions still apply for production technology options for
smallholder farmers in Marondera and Goromonzi
Assumptions
(a)7 person household with 6 labour unit,famlab=6*26*6=936
(b)Family consumption requirement for maize per year
FAMCONREQ=120kg*6=720kg
(c)FARM ACTIVITIES: MIXED FARMING
ENTERPRISE,chili,MAIZE,sugarbeans,groundnuts,
(d)Complete markets exist for all crops and food stuffs

!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
Specification of the Objective Function of the household;

[objective]             Max    = Y;
[PROFIT]                Y = Ychili+Ysbeans+Ygnuts+Ymaize-
Pmaizebuying*Qmaizebuy
                            +(labout*wageout-labin*wagein);
[GMchili]          Ychili = Qchilsold*Pchili-VCchil1*Achil1-vcCHIL2*ACHIL2;
[GMsugarbeans]     Ysbeans= Qsbeansold*Psbeans-VCsbeans*Asbeans;
[GMgroundnuts]     Ygnuts = Qgnutsold*Pgnuts-VCgnuts*Agnuts;
[GMmaize]          Ymaize = Qmaizesold*Pmaize-VCmaize*Amaize;
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CONSTRAINTS
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
[TOTAL_LAND]             Achil1+Achil2+Asbeans+Agnuts+Amaize<=6;
[TOTAL_LABOUR]     Amaize*120+Asbeans*160+Agnuts*140+Achil1*140+Achil2*240
                         <=ownlab+labin;
[BUDGET]           175*Amaize +248*Asbeans +190*Achil1 +Achil2*50
                  +Agnuts*132 +qmaizebuy*pmaizebuying <=1000
                  +labout*wageout -labin*wagein;

[famlabbalance]          ownlab+labout<=famsize*6*26;
[chil2lim]               ACHIL2<=ACHIL1;

[FOODSECURITY]          Qmaizecons>=famsize*50;
![maizebuylimit]         qmaizebuy<=150;
[foodsecurity2]         Qgnutcons>=10*famsize;
[FOODSECURITY3]         QSBEANCONS>=10*famsize;

!+[LABORBAL]
      120*AMAIZE+160*ASBEANS+140*ACHILI+Lchil2*240+160*AGNUTS <= FAMLAB
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
!crop utilization
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
```

```
[maizebal]              Yieldmaize*Amaize+Qmaizebuy-Qmaizesold-Qmaizecons=0;
[sugarbeanbal]          Yieldsbean*Asbeans-Qsbeansold-Qsbeancons=0;
[chilibal]              Yieldchil1*Achil1+Yieldchil2*Achil2-Qchilsold=0;
[groundnutbal]          Yieldgnut*Agnuts-Qgnutsold-qgnutcons=0;
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
!Parameters
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
Data:Pchili,Psbeans,Pgnuts,Pmaize, Pmaizebuying=3,1,1,0.3,0.4;Enddata
Data:VCchil1,VCCHIL2,VCsbeans,VCgnuts,VCmaize =190,50,248,132,175;Enddata
Data:yieldmaize,yieldgnut,yieldsbean,yieldchil1,yieldchil2
=833,481,428,190,200;Enddata
Data: famsize,wagein,wageout=6,2,3;enddata
```

```
Global optimal solution found.
  Objective value:                              2912.333
  Infeasibilities:                              0.000000
  Total solver iterations:                             7
```

Variable	Value	Reduced Cost
Y	2912.333	0.000000
YCHILI	0.000000	0.000000
YSBEANS	0.000000	1.161111
YGNUTS	1917.667	0.000000
YMAIZE	0.000000	0.3333333
PMAIZEBUYING	0.4000000	0.000000
QMAIZEBUY	300.0000	0.000000
LABOUT	936.0000	0.000000
WAGEOUT	3.000000	0.000000
LABIN	846.6667	0.000000
WAGEIN	2.000000	0.000000
QCHILSOLD	0.000000	0.000000
PCHILI	0.000000	0.000000
VCCHIL1	0.000000	0.000000
ACHIL1	0.000000	349.0000
VCCHIL2	0.000000	0.000000
ACHIL2	0.000000	549.0000
QSBEANSOLD	82.66667	0.000000
PSBEANS	1.000000	0.000000
VCSBEANS	248.0000	0.000000
ASBEANS	0.3333333	0.000000
QGNUTSOLD	2665.667	0.000000
PGNUTS	1.000000	0.000000
VCGNUTS	132.0000	0.000000
AGNUTS	5.666667	0.000000
QMAIZESOLD	0.000000	0.000000
PMAIZE	0.3000000	0.000000
VCMAIZE	175.0000	0.000000
AMAIZE	0.000000	209.1333
OWNLAB	0.000000	1.000000
FAMSIZE	6.000000	0.000000
QMAIZECONS	300.0000	0.000000
QGNUTCONS	60.00000	0.000000
QSBEANCONS	60.00000	0.000000
YIELDMAIZE	833.0000	0.000000
YIELDSBEAN	428.0000	0.000000
YIELDCHIL1	0.000000	0.000000

YIELDCHIL2	0.000000	0.000000
YIELDGNUT	481.0000	0.000000

Row	Slack or Surplus	Dual Price
OBJECTIVE	2912.333	1.000000
PROFIT	0.000000	1.000000
GMCHILI	0.000000	1.000000
GMSUGARBEANS	0.000000	2.161111
GMGROUNDNUTS	0.000000	1.000000
GMMAIZE	0.000000	1.333333
TOTAL_LAND	0.000000	69.00000
TOTAL_LABOUR	0.000000	2.000000
BUDGET	1164.000	0.000000
FAMLABBALANCE	0.000000	3.000000
CHIL2LIM	0.000000	0.000000
FOODSECURITY	0.000000	-0.4000000
FOODSECURITY2	0.000000	-1.000000
FOODSECURITY3	0.000000	-2.161111
MAIZEBAL	0.000000	-0.4000000
SUGARBEANBAL	0.000000	-2.161111
CHILIBAL	0.000000	0.000000
GROUNDNUTBAL	0.000000	-1.000000

Appendix B2 Linear programming results: Optimum model (S1)

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
CHILI PRODUCTION SYSTEM
- Chili is grown over 18 months and harvested for 12 months after planting
- Thus a chili cropland is out of circulation for two seasons
- Land is not scarce but labor is scarce

SCENARIO ANALYSIS - SMALLHOLDER FARMER HAS OPTION
(A) TO ENGAGE IN A MARKETING CONTRACT
(B) TO ENGAGE IN A PRODUCTION AND MARKETING CONTRACT

Basic assumptions still apply for production technology options for
smallholder farmers in Marondera and Goromonzi
Assumptions
(a)7 person household with 6 labour unit,famlab=6*26*6=936
(b)Family consumption requirement for maize per year
FAMCONREQ=120kg*6=720kg
(c)FARM ACTIVITIES: MIXED FARMING
ENTERPRISE,chili,MAIZE,sugarbeans,groundnuts,
(d)Complete markets exist for all crops and food stuffs

!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
Specification of the Objective Function of the household;

[objective]             Max    = Y;
[PROFIT]                Y = Ychili+Ysbeans+Ygnuts+Ymaize-
Pmaizebuying*Qmaizebuy
                            +(labout*wageout-labin*wagein);
[GMchili]          Ychili = Qchilsold*Pchili-VCchil1*Achil1-vcCHIL2*ACHIL2;
[GMsugarbeans]     Ysbeans= Qsbeansold*Psbeans-VCsbeans*Asbeans;
[GMgroundnuts]     Ygnuts = Qgnutsold*Pgnuts-VCgnuts*Agnuts;
[GMmaize]          Ymaize = Qmaizesold*Pmaize-VCmaize*Amaize;
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CONSTRAINTS
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
[TOTAL_LAND]             Achil1+Achil2+Asbeans+Agnuts+Amaize<=6;
[TOTAL_LABOUR]     Amaize*120+Asbeans*160+Agnuts*140+Achil1*140+Achil2*240
                         <=ownlab+labin;
[BUDGET]           175*Amaize +248*Asbeans +190*Achil1 +Achil2*50
                  +Agnuts*132 +qmaizebuy*pmaizebuying <=1000
                  +labout*wageout -labin*wagein;

[famlabbalance]          ownlab+labout<=famsize*6*26;
[chil2lim]               ACHIL2<=ACHIL1;

[FOODSECURITY]          Qmaizecons>=famsize*50;
![maizebuylimit]         qmaizebuy<=150;
[foodsecurity2]         Qgnutcons>=10*famsize;
[FOODSECURITY3]         QSBEANCONS>=10*famsize;

!+[LABORBAL]
      120*AMAIZE+160*ASBEANS+140*ACHILI+Lchil2*240+160*AGNUTS <= FAMLAB
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
!crop utilization
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
[maizebal]            Yieldmaize*Amaize+Qmaizebuy-Qmaizesold-Qmaizecons=0;
[sugarbeanbal]        Yieldsbean*Asbeans-Qsbeansold-Qsbeancons=0;
[chilibal]            Yieldchil1*Achil1+Yieldchil2*Achil2-Qchilsold=0;
[groundnutbal]        Yieldgnut*Agnuts-Qgnutsold-qgnutcons=0;
```

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
!Parameters
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
Data:Pchili,Psbeans,Pgnuts,Pmaize, Pmaizebuying=3,1,1,0.3,0.4;Enddata
Data:VCchil1,VCCHIL2,VCsbeans,VCgnuts,VCmaize =190,50,248,132,175;Enddata
Data:yieldmaize,yieldgnut,yieldsbean,yieldchil1,yieldchil2
=833,481,428,190,200;Enddata
Data: famsize,wagein,wageout=6,2,3;enddata
```

```
Global optimal solution found.
  Objective value:                              3082.670
  Infeasibilities:                              0.000000
  Total solver iterations:                             8
```

Variable	Value	Reduced Cost
Y	3082.670	0.000000
YCHILI	2088.004	0.000000
YSBEANS	0.000000	1.333333
YGNUTS	0.000000	0.8882521E-01
YMAIZE	0.000000	0.3333333
PMAIZEBUYING	0.4000000	0.000000
QMAIZEBUY	300.0000	0.000000
LABOUT	936.0000	0.000000
WAGEOUT	3.000000	0.000000
LABIN	846.6667	0.000000
WAGEIN	2.000000	0.000000
QCHILSOLD	1044.002	0.000000
PCHILI	3.000000	0.000000
VCCHIL1	190.0000	0.000000
ACHIL1	5.494747	0.000000
VCCHIL2	50.00000	0.000000
ACHIL2	0.000000	30.00000
QSBEANSOLD	82.66667	0.000000
PSBEANS	1.000000	0.000000
VCSBEANS	248.0000	0.000000
ASBEANS	0.3333333	0.000000
QGNUTSOLD	22.69341	0.000000
PGNUTS	1.000000	0.000000
VCGNUTS	132.0000	0.000000
AGNUTS	0.1719198	0.000000
QMAIZESOLD	0.000000	0.000000
PMAIZE	0.3000000	0.000000
VCMAIZE	175.0000	0.000000
AMAIZE	0.000000	240.1333
OWNLAB	0.000000	1.000000
FAMSIZE	6.000000	0.000000
QMAIZECONS	300.0000	0.000000
QGNUTCONS	60.00000	0.000000
QSBEANCONS	60.00000	0.000000
YIELDMAIZE	833.0000	0.000000
YIELDSBEAN	428.0000	0.000000
YIELDCHIL1	190.0000	0.000000
YIELDCHIL2	200.0000	0.000000
YIELDGNUT	481.0000	0.000000

Row	Slack or Surplus	Dual Price
OBJECTIVE	3082.670	1.000000
PROFIT	0.000000	1.000000
GMCHILI	0.000000	1.000000
GMSUGARBEANS	0.000000	2.333333
GMGROUNDNUTS	0.000000	1.088825
GMMAIZE	0.000000	1.333333
TOTAL_LAND	0.000000	100.0000
TOTAL_LABOUR	0.000000	2.000000
BUDGET	845.3047	0.000000
FAMLABBALANCE	0.000000	3.000000
CHIL2LIM	5.494747	0.000000
FOODSECURITY	0.000000	-0.4000000
FOODSECURITY2	0.000000	-1.088825
FOODSECURITY3	0.000000	-2.333333
MAIZEBAL	0.000000	-0.4000000
SUGARBEANBAL	0.000000	-2.333333
CHILIBAL	0.000000	-3.000000
GROUNDNUTBAL	0.000000	-1.088825

Appendix B3 Sensitivity analysis (S2) percentage change in land

```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
CHILI PRODUCTION SYSTEM
- Chili is grown over 18 months and harvested for 12 months after planting
- Thus a chili cropland is out of circulation for two seasons
- Land is not scarce but labor is scarce

SCENARIO ANALYSIS - SMALLHOLDER FARMER HAS OPTION
(A) TO ENGAGE IN A MARKETING CONTRACT
(B) TO ENGAGE IN A PRODUCTION AND MARKETING CONTRACT

Basic assumptions still apply for production technology options for
smallholder farmers in Marondera and Goromonzi
Assumptions
(a)7 person household with 6 labour unit,famlab=6*26*6=936
(b)Family consumption requirement for maize per year
FAMCONREQ=120kg*6=720kg
(c)FARM ACTIVITIES: MIXED FARMING
ENTERPRISE,chili,MAIZE,sugarbeans,groundnuts,
(d)Complete markets exist for all crops and food stuffs

!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
Specification of the Objective Function of the household;

[objective]             Max    = Y;
[PROFIT]                Y = Ychili+Ysbeans+Ygnuts+Ymaize-
Pmaizebuying*Qmaizebuy
                            +(labout*wageout-labin*wagein);
[GMchili]          Ychili = Qchilsold*Pchili-VCchil1*Achil1-vcCHIL2*ACHIL2;
[GMsugarbeans]     Ysbeans= Qsbeansold*Psbeans-VCsbeans*Asbeans;
[GMgroundnuts]     Ygnuts = Qgnutsold*Pgnuts-VCgnuts*Agnuts;
[GMmaize]          Ymaize = Qmaizesold*Pmaize-VCmaize*Amaize;
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
CONSTRAINTS
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
[TOTAL_LAND]             Achil1+Achil2+Asbeans+Agnuts+Amaize<=6.6;
[TOTAL_LABOUR]     Amaize*120+Asbeans*160+Agnuts*140+Achil1*140+Achil2*240
                         <=ownlab+labin;
[BUDGET]           175*Amaize +248*Asbeans +190*Achil1 +Achil2*50
                  +Agnuts*132 +qmaizebuy*pmaizebuying <=1000
                  +labout*wageout -labin*wagein;

[famlabbalance]          ownlab+labout<=famsize*6*26;
[chil2lim]               ACHIL2<=ACHIL1;

[FOODSECURITY]          Qmaizecons>=famsize*50;
![maizebuylimit]         qmaizebuy<=150;
[foodsecurity2]         Qgnutcons>=10*famsize;
[FOODSECURITY3]         QSBEANCONS>=10*famsize;

!+[LABORBAL]
      120*AMAIZE+160*ASBEANS+140*ACHILI+Lchil2*240+160*AGNUTS <= FAMLAB
```

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
!crop utilization
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
[maizebal]             Yieldmaize*Amaize+Qmaizebuy-Qmaizesold-Qmaizecons=0;
[sugarbeanbal]         Yieldsbean*Asbeans-Qsbeansold-Qsbeancons=0;
[chilibal]             Yieldchil1*Achil1+Yieldchil2*Achil2-Qchilsold=0;
[groundnutbal]         Yieldgnut*Agnuts-Qgnutsold-qgnutcons=0;
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
!Parameters
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
Data:Pchili,Psbeans,Pgnuts,Pmaize, Pmaizebuying=3,1,1,0.3,0.4;Enddata
Data:VCchil1,VCCHIL2,VCsbeans,VCgnuts,VCmaize =190,50,248,132,175;Enddata
Data:yieldmaize,yieldgnut,yieldsbean,yieldchil1,yieldchil2
=833,481,428,190,200;Enddata
Data: famsize,wagein,wageout=6,2,3;enddata
```

```
Global optimal solution found.
  Objective value:                              3142.670
  Infeasibilities:                              0.000000
  Total solver iterations:                             8
```

Variable	Value	Reduced Cost
Y	3142.670	0.000000
YCHILI	2316.004	0.000000
YSBEANS	0.000000	1.333333
YGNUTS	0.000000	0.8882521E-01
YMAIZE	0.000000	0.3333333
PMAIZEBUYING	0.4000000	0.000000
QMAIZEBUY	300.0000	0.000000
LABOUT	936.0000	0.000000
WAGEOUT	3.000000	0.000000
LABIN	930.6667	0.000000
WAGEIN	2.000000	0.000000
QCHILSOLD	1158.002	0.000000
PCHILI	3.000000	0.000000
VCCHIL1	190.0000	0.000000
ACHIL1	6.094747	0.000000
VCCHIL2	50.00000	0.000000
ACHIL2	0.000000	30.00000
QSBEANSOLD	82.66667	0.000000
PSBEANS	1.000000	0.000000
VCSBEANS	248.0000	0.000000
ASBEANS	0.3333333	0.000000
QGNUTSOLD	22.69341	0.000000
PGNUTS	1.000000	0.000000
VCGNUTS	132.0000	0.000000
AGNUTS	0.1719198	0.000000
QMAIZESOLD	0.000000	0.000000
PMAIZE	0.3000000	0.000000
VCMAIZE	175.0000	0.000000
AMAIZE	0.000000	240.1333
OWNLAB	0.000000	1.000000
FAMSIZE	6.000000	0.000000
QMAIZECONS	300.0000	0.000000
QGNUTCONS	60.00000	0.000000

```
      QSBEANCONS        60.00000            0.000000
      YIELDMAIZE        833.0000            0.000000
      YIELDSBEAN        428.0000            0.000000
      YIELDCHIL1        190.0000            0.000000
      YIELDCHIL2        200.0000            0.000000
       YIELDGNUT        481.0000            0.000000

             Row    Slack or Surplus      Dual Price
       OBJECTIVE        3142.670            1.000000
          PROFIT        0.000000            1.000000
         GMCHILI        0.000000            1.000000
    GMSUGARBEANS        0.000000            2.333333
    GMGROUNDNUTS        0.000000            1.088825
          GMMAIZE       0.000000            1.333333
      TOTAL_LAND        0.000000            100.0000
    TOTAL_LABOUR        0.000000            2.000000
          BUDGET        563.3047            0.000000
   FAMLABBALANCE        0.000000            3.000000
        CHIL2LIM        6.094747            0.000000
    FOODSECURITY        0.000000          -0.4000000
   FOODSECURITY2        0.000000           -1.088825
   FOODSECURITY3        0.000000           -2.333333
        MAIZEBAL        0.000000          -0.4000000
    SUGARBEANBAL        0.000000           -2.333333
        CHILIBAL        0.000000           -3.000000
    GROUNDNUTBAL        0.000000           -1.088825
```

Appendix B4 Sensitivity analysis: S4 percentage change in labor

```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
CHILI PRODUCTION SYSTEM
- Chili is grown over 18 months and harvested for 12 months after planting
- Thus a chili cropland is out of circulation for two seasons
- Land is not scarce but labor is scarce

SCENARIO ANALYSIS - SMALLHOLDER FARMER HAS OPTION
(A) TO ENGAGE IN A MARKETING CONTRACT
(B) TO ENGAGE IN A PRODUCTION AND MARKETING CONTRACT

Basic assumptions still apply for production technology options for
smallholder farmers in Marondera and Goromonzi
Assumptions
(a)7 person household with 6 labour unit,famlab=6*26*6=936
(b)Family consumption requirement for maize per year
FAMCONREQ=120kg*6=720kg
(c)FARM ACTIVITIES: MIXED FARMING
ENTERPRISE,chili,MAIZE,sugarbeans,groundnuts,
(d)Complete markets exist for all crops and food stuffs

!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
Specification of the Objective Function of the household;

[objective]             Max    = Y;
[PROFIT]                Y = Ychili+Ysbeans+Ygnuts+Ymaize-
Pmaizebuying*Qmaizebuy
                            +(labout*wageout-labin*wagein);
[GMchili]          Ychili = Qchilsold*Pchili-VCchil1*Achil1-vcCHIL2*ACHIL2;
[GMsugarbeans]     Ysbeans= Qsbeansold*Psbeans-VCsbeans*Asbeans;
[GMgroundnuts]     Ygnuts = Qgnutsold*Pgnuts-VCgnuts*Agnuts;
[GMmaize]          Ymaize = Qmaizesold*Pmaize-VCmaize*Amaize;
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
CONSTRAINTS
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
[TOTAL_LAND]             Achil1+Achil2+Asbeans+Agnuts+Amaize<=6.6;
[TOTAL_LABOUR]     Amaize*120+Asbeans*160+Agnuts*140+Achil1*140+Achil2*240
                         <=ownlab+labin;
[BUDGET]           175*Amaize +248*Asbeans +190*Achil1 +Achil2*50
                  +Agnuts*132 +qmaizebuy*pmaizebuying <=1000
                  +labout*wageout -labin*wagein;

[famlabbalance]          ownlab+labout<=famsize*6*26;
[chil2lim]               ACHIL2<=ACHIL1;

[FOODSECURITY]          Qmaizecons>=famsize*50;
![maizebuylimit]         qmaizebuy<=150;
[foodsecurity2]         Qgnutcons>=10*famsize;
[FOODSECURITY3]         QSBEANCONS>=10*famsize;

!+[LABORBAL]
      120*AMAIZE+160*ASBEANS+140*ACHILI+Lchil2*240+160*AGNUTS <= FAMLAB
```

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
!crop utilization
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
[maizebal]             Yieldmaize*Amaize+Qmaizebuy-Qmaizesold-Qmaizecons=0;
[sugarbeanbal]         Yieldsbean*Asbeans-Qsbeansold-Qsbeancons=0;
[chilibal]             Yieldchil1*Achil1+Yieldchil2*Achil2-Qchilsold=0;
[groundnutbal]         Yieldgnut*Agnuts-Qgnutsold-qgnutcons=0;
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
!Parameters
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
Data:Pchili,Psbeans,Pgnuts,Pmaize, Pmaizebuying=3,1,1,0.3,0.4;Enddata
Data:VCchil1,VCCHIL2,VCsbeans,VCgnuts,VCmaize =190,50,248,132,175;Enddata
Data:yieldmaize,yieldgnut,yieldsbean,yieldchil1,yieldchil2
=833,481,428,190,200;Enddata
Data: famsize,wagein,wageout=6,2.20,3;enddata
```

```
Global optimal solution found.
  Objective value:                              2913.337
  Infeasibilities:                              0.000000
  Total solver iterations:                             8
```

Variable	Value	Reduced Cost
Y	2913.337	0.000000
YCHILI	2088.004	0.000000
YSBEANS	0.000000	1.355556
YGNUTS	0.000000	0.8882521E-01
YMAIZE	0.000000	0.3333333
PMAIZEBUYING	0.4000000	0.000000
QMAIZEBUY	300.0000	0.000000
LABOUT	936.0000	0.000000
WAGEOUT	3.000000	0.000000
LABIN	846.6667	0.000000
WAGEIN	2.200000	0.000000
QCHILSOLD	1044.002	0.000000
PCHILI	3.000000	0.000000
VCCHIL1	190.0000	0.000000
ACHIL1	5.494747	0.000000
VCCHIL2	50.00000	0.000000
ACHIL2	0.000000	50.00000
QSBEANSOLD	82.66667	0.000000
PSBEANS	1.000000	0.000000
VCSBEANS	248.0000	0.000000
ASBEANS	0.3333333	0.000000
QGNUTSOLD	22.69341	0.000000
PGNUTS	1.000000	0.000000
VCGNUTS	132.0000	0.000000
AGNUTS	0.1719198	0.000000
QMAIZESOLD	0.000000	0.000000
PMAIZE	0.3000000	0.000000
VCMAIZE	175.0000	0.000000
AMAIZE	0.000000	236.1333
OWNLAB	0.000000	0.8000000
FAMSIZE	6.000000	0.000000
QMAIZECONS	300.0000	0.000000
QGNUTCONS	60.00000	0.000000
QSBEANCONS	60.00000	0.000000

YIELDMAIZE	833.0000	0.000000
YIELDSBEAN	428.0000	0.000000
YIELDCHIL1	190.0000	0.000000
YIELDCHIL2	200.0000	0.000000
YIELDGNUT	481.0000	0.000000

Row	Slack or Surplus	Dual Price
OBJECTIVE	2913.337	1.000000
PROFIT	0.000000	1.000000
GMCHILI	0.000000	1.000000
GMSUGARBEANS	0.000000	2.355556
GMGROUNDNUTS	0.000000	1.088825
GMMAIZE	0.000000	1.333333
TOTAL_LAND	0.000000	72.00000
TOTAL_LABOUR	0.000000	2.200000
BUDGET	675.9713	0.000000
FAMLABBALANCE	0.000000	3.000000
CHIL2LIM	5.494747	0.000000
FOODSECURITY	0.000000	-0.4000000
FOODSECURITY2	0.000000	-1.088825
FOODSECURITY3	0.000000	-2.355556
MAIZEBAL	0.000000	-0.4000000
SUGARBEANBAL	0.000000	-2.355556
CHILIBAL	0.000000	-3.000000
GROUNDNUTBAL	0.000000	-1.088825

APPENDIX C QUESTIONNAIRE