

MAIZE AND SORGHUM TECHNOLOGIES AND THE EFFECTS OF MARKETING
STRATEGIES ON FARMERS' INCOME IN MOZAMBIQUE

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LIST OF ACRONYMS

ACDI/VOCA - Agricultural Cooperative Development International (ACDI) and
Volunteers in Overseas Cooperative Assistance (VOCA)

CAP – Censo Agro-Pecuário

CIMMYT- International Maize and Wheat Improvement Center

CLUSA- Cooperative League USA

DANIDA- Danish International Development Agency

DNCI – Direção Nacional de Comércio Interno

FAO – Food and Agriculture Organization

GAMS- General Algebraic Modeling Systems

ICRISAT – International Crops Research Institute for the Semi-Arid Tropics

INAM – Instituto Nacional de Meteorologia de Moçambique

INE – Instituto Nacional de Estatística

INIA – Instituto Nacional de Investigação Agronómica

ITDG- Intermediate Technology Development Group

Kg - Kilogram

MZM – Metical

NGO- Non Governmental Organization

NPK – Nitrogen, Phosphate, Potassium Complex Fertilizer (12-24-12)

OPV – Open Pollinated Variety

PAMA – Programa de Apoio aos Mercados Agrícolas

PAN- Programa de Acção Nacional

PANNAR- South African based Seed Company

PDE – Person-Day-Equivalent

PROAGRI – Programa de Agricultura

QPM- Quality Protein Maize

SADC – Southern Africa Development Community

SEMOC – Sementes de Moçambique SARL

SG2000 – Sasakiwa Global 2000

SIMA – Sistema de Informação de Mercados Agrícolas

SMIP- Sorghum and Millet Improvement Program

SNAP – Sistema Nacional de Aviso Prévio

TECHNOSERVE- A Non-profit 501 Organization

UCAMA- União de Camponeses de Manica

ABSTRACT

Uaiene, Rafael N., M.S., Purdue University, December, 2004. Maize and Sorghum Technologies and the Effects of Marketing Strategies on Farmers' Income in Mozambique. Major Professor: John H. Sanders, College of Agriculture.

About three-quarter of Mozambicans depend on agriculture for their livelihoods. Maize and sorghum are major crops and food staples. Given limited off-farm employment opportunities, increase in farm household income and food security will come from gains in agricultural productivity through better more profitable technologies.

The adoption of agricultural technologies, especially of new maize-fertilizer based technologies is constrained by the low prices received by farmers in Mozambique. While urban and rural poor benefit from low agricultural prices, it is bound to harm the incentives of producers, the agricultural technology users, and ultimately affecting the momentum of agricultural growth.

There are three principal factors responsible for these low prices: seasonal price variation, price collapse in good years, and public policies that depress producer prices in adverse weather years. The thesis analyzes the effect of higher output prices on the adoption of new technologies and farmers' income for maize and sorghum-fertilizer based technologies in Manica. A farm household model is used to evaluate the potential impacts of the improved technologies with and without marketing strategies to address

the constraints of low output prices. This model takes into account the household harvest income and food subsistence requirements of farmers.

The marketing strategies tested were: a) inventory credit that allows farmers to exploit seasonal price variation; b) cereal market expansion through food and feed processing and c) policies that do not depress prices in bad production years.

Modeling results indicate that farm household income increases 58% with the introduction of inventory credit with new technologies as a result of maize intensification. A strategy to moderate price collapse between years due to inelastic demand and good weather combined with storage and inventory credit increases farm income by 71%. The combination of all marketing strategies and new maize technologies increase the average farmer's household income by 81%.

Finally, the high shadow prices with the present liquidity indicate a potential dynamic effect. Potentially, farmers can earn increased profits from the system and reinvest them on new maize technologies, so that the ultimate income effects will be even greater.

CHAPTER I

INTRODUCTION

1.1 Background

Agricultural technologies aiming at increasing productivity of sorghum and maize, as well as improving income and level of living of small scale farmers, are not widely adopted in Mozambique. At the country level only 5 to 10% of total maize area has been planted to improved maize (Libombo and Uaiene, 1999).

Large yield increases of both maize and sorghum are possible with the use of fertilizer and improved cultivars as demonstrated by research and extension systems in Mozambique. Most farmers cultivate small areas (1-2 ha) of these cereals and have not adopted improved agronomic methods. The use of external inputs (i.e. chemical fertilizers and agro-chemicals and to a large extent, seed of improved varieties), is limited primarily to those which are subsidized by government and non-governmental organizations (NGOs).

The adoption of new maize and sorghum technologies has been slow in Mozambique. A farmer's decisions, about whether to adopt a technology package will depend not only on the yield increases achieved, but primarily the profitability of new

technology (Binswanger and Rosenzweig, 1986). The slow adoption of new maize and sorghum packages in Mozambique is hypothesized, to be caused by low profitability due to: price collapse at harvest when most of grain is sold; price collapse in good rainfall years, due to increased supply and the inelastic demand for a staple food¹; and in bad years when there is short supply of grain, the price do not rise enough due to government and non-governmental intervention to keep food price low.

Large within season and between seasons producer price variation is observed in grains especially maize grain in Mozambique. Nominal price data for Manica show that maize prices doubled from June through December peak (SIMA 2002)². Maize is not only key to household consumption, but it is also key to household income, thus, price variability has a large impact on rural household welfare.

Low output producer prices at harvesting time (between May and July) are expected to reduce farmers' incentives to utilize new technologies including new varieties, fertilizers or other agricultural inputs. Low returns on farm-gate sales result in lack of purchasing power and low effective demand for inputs. Sanders et al (1996, p. 136), recognized that price collapses by reducing expected incomes and increasing income variability, can be a principal disincentive to adopting new technologies. Using input profitability analysis with data collected on farm-level impact of Sasakawa Global 2000 (SG2000) technologies (improved maize and fertilizer), Howard et al. (2000) suggested that farmers would dramatically increase their gains if they could store for

¹ The inelastic demand for staple food is due to the fact that those with sufficient incomes to buy food and those producing can only eat as much. Increased trade will make demand less inelastic.

² Producer's maize price average in June (1995-2002), at harvest, is MZM740.00/kg (US\$0.03/kg), while for the same period producer's price in December average MZM1,826/kg (US\$0.076/kg), an increase of more than 145%.

several months instead of selling immediately after harvest. Only 36% of farmers selling at harvest made profits, while 80% of those selling at December price made profits using the new maize package (Howard et al., 2000).

The second form of output price variability is the year-to-year variability due to price inelasticity of demand. Shapiro and Sanders, (2002) reported major losses for producers as a result of price collapses due to a combination of good weather and rapid technological change for maize in Ethiopia in 1996 and 2001. When harvest is good (due to good weather and or new technology) and the farm household could have a marketed surplus, the price falls because all households also have plentiful harvest. Even with the large drop in prices, most consumers do not eat more. Because this price collapse can offset the effect of larger harvest, the average farmer's income can decline.

1.2 The Problem

The basic problem addressed by this thesis is: would improved marketing strategies make it sufficiently profitable for farmers to adopt new technologies in maize and sorghum production? The answer to this question will help understand the farmer's decision making and help frame policies to improve adoption of improved agricultural technologies that have profound impact on farmer's food security and income levels.

The main hypothesis is thus that by giving producers the opportunity to receive higher prices via marketing strategies they will then adopt new technologies since it will become more profitable to adopt the new seed-fertilizer technologies, and thereby accelerate the diffusion process.

1.3 Objectives

The objective of this thesis is to analyze the impacts of higher output prices on the adoption of improved maize and sorghum technologies by farmers in Mozambique. The specific objectives are:

1. Estimate the profitability of new maize and sorghum technological packages.
2. Estimate the potential effects of different market strategies and their interaction with new technologies on adoption and farmers' incomes.
3. Recommend policies that will help government, non-government organizations and farmers to foster adoption and diffusion of new agricultural production technologies and marketing strategies that will allow increase in farmers' incomes.

1.4 Summary of Procedure

The analysis is based on crop partial budgeting and whole farm household model developed for an average farm household in the Manica province of Mozambique. The model evaluates adoption and profitability of maize cultivar-fertilizer based technologies as well as their interaction with marketing strategies in Manica, a prime zone for agricultural production in Mozambique.

1.5 Thesis Organization

The next chapter presents the study area, the farm household characteristics and discusses the maize and sorghum economy in Mozambique with particular reference to Manica. A comparison between these two important cereals is carried out in terms of

technologies, maize and sorghum partial budgets, farming systems, production, marketing, consumption systems, and price variability. The technologies and marketing strategies considered in the thesis are presented and discussed in Chapter 3. In Chapter 4, the conceptual and empirical framework of household farm model is presented and the interaction between marketing strategies and technologies discussed. Model validation is presented in Chapter 5. The interactions between new technologies and marketing strategies are presented and discussed in Chapter 6 and finally, Chapter 7 presents conclusions, policy recommendations and suggestions for future research.

CHAPTER II

STUDY AREA

2.1 Introduction

The study area covers the districts of Gondola, Manica and Sussundenga in Manica Province, one of the ten provinces of Mozambique. The area was selected because it is a prime agricultural area in Mozambique with a maize-sorghum based farming system. Manica Province has the highest concentration of the national agricultural knowledge system in the country. The national maize and sorghum improvement program is based in Sussundenga Research Station. Manica has always benefited from government and non-government extension services. Programs such as Sasakawa Global 2000 (SG2000), the United Nations Food and Agriculture Organization (FAO) Special Program (PAN), and Technoserve are active here.

This chapter presents a description of the region, farming system, cereal production and marketing as well as survey data collected. The survey data includes the farm household's characteristics, income and expenditure.

2.2 Location and Characteristics of the Study Area

Manica province borders Zimbabwe to the west, Tete to the north, Sofala to the east, Inhambane and Gaza to the south (Figure 2.1). Three important topographic features influence agriculture in the province: the western mountain range; the central plateau; and

a series of valleys along the Pungue and Buzi rivers and the tributaries of the Zambezi and Save rivers. The province has large tracts of fertile soils in the districts of Gondola, Manica, Sussundenga, Mossurize and Barue. The predominant soils in Manica are Ferralsols (INIA, 1997).

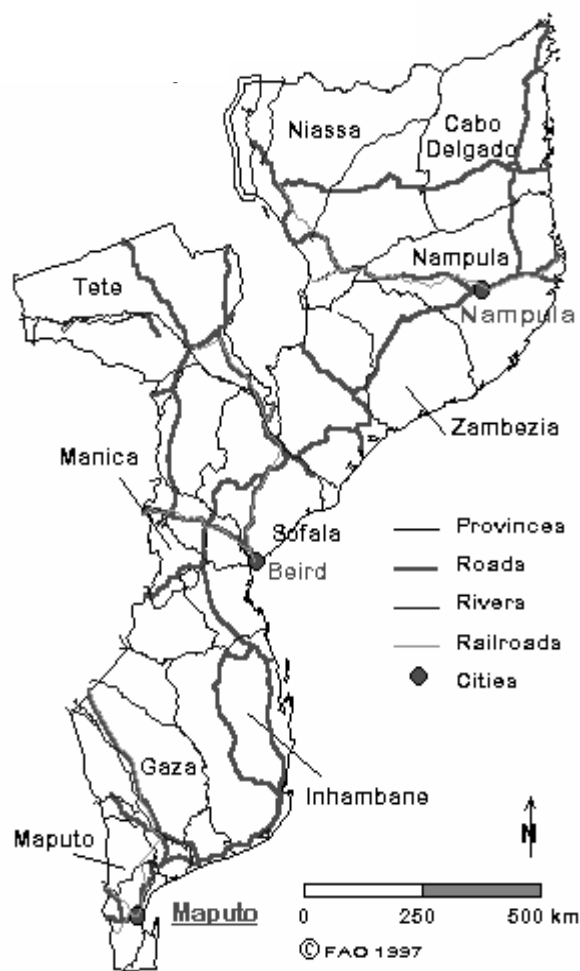


Figure 2.1 Map of Mozambique.

The selected districts are within easy access (radius of 60 km) from Chimoio, the capital city and connect well with major cities such as Beira, Tete and even with the neighboring Zimbabwe. Although roads are generally a major problem in the

country the region has permanent passable roads. A feeder road rehabilitation program funded by DANIDA is underway in the districts of Gondola, Manica and Sussundenga (ITDG, 2003).

2.3 Climate

Manica's climate is, in general, moderated by its relatively high altitude (200-2436 m above the sea level). Average high midsummer temperatures are only about 25°C and in the winter months of June and July temperatures often drop to 15°C at night. The rainfall is unimodal and it can reach 250 mm/month in the peak wet months of December and January but as low as 10 mm in the drier months of June and July. The average annual rainfall in Manica is over 1,100 mm (INAM, 2003). The climate is conducive to rich and varied agricultural production.

2.4 Farming Systems

The farming systems in Manica Province is maize based, followed by sorghum, millet, cowpeas, beans and groundnuts; rice and cassava are minor crops. Tobacco, cotton and sunflower are important cash crops in the province. There is very little animal production in the province as most of the province suffers from tse-tse fly infestation. Moreover, a significant number of animals were lost during the sixteen years of civil war, which ended in 1992.

Soils vary from red clay to shallow stoney soils. The soils have different fertility status and are used for different cropping systems. Maize, sorghum, beans, and cotton are grown in the most fertile soils, the red clay soils. The higher the soil fertility, the longer is

the period of sequential cultivation or the shorter the period under fallow (CIMMYT, 2003).

The spatial distribution of fertility classes of Mozambique (Geurts, 1997) indicates that, except for alluvial soils, the soils of Mozambique vary from moderate to low fertility. In cultivated areas depletion of nutrients is caused by the imbalance between the output of nutrients (mainly through crop harvest and erosion) and the input of nutrients (in form of organic and inorganic fertilizers), resulting in a negative nutrient balance of the soil and its consequent gradual loss of soil productivity. The areas used for small-scale farming in Manica, have moderate-to-high nutrient mining due to low levels of inputs used for crop production. The soil fertility mining is worsened by reduced fallow periods and population pressure. This soil fertility mining and other forms of soil degradation threaten the future of already low soil productivity. Low purchased of input use dominates the small-scale farming that produces most of sorghum and maize in Manica.

In Manica, farmers grow local varieties and are adopting some new improved maize varieties. Most of the land area remains planted to local varieties. Local varieties are preferred by farmers for their good milling characteristics and resistance to weevil when compared to most improved cultivars (open pollinated varieties or hybrids). New cultivars were often seen by the interviewed farmers as a risk-avoidance (drought escape) strategy through early maturing cultivars. Short season maize varieties like Matuba can be cultivated in wetlands as a strategy to provide an early supply of maize. Most farmers use their own retained seeds (CIMMYT, 2003).

Twenty three percent of interviewed maize producers in Manica use some form of the new maize technologies being promoted (Uaiene, 2003). Understanding the factors that affects the adoption and diffusion of the technology in this prime agricultural area will help the diffusion process across the country.

Increases in maize and sorghum production, despite some year-to-year variation due to weather and growing conditions are expected from crop intensification³ rather than change in area under these two cereals. Yields are still relatively low even when compared to the neighboring countries. The population pressure of 2.5% growth per in year (INE, 2003), will make continuous area expansion difficult especially in the prime agricultural lands of Manica.

2.4.1 Maize Production in Manica

The province is generally a surplus maize grain producer, which makes it a preferred destination for formal and informal buyers⁴ of maize grain. Manica contributes about 20% of national maize production (SNAP, 2002). Manica province is the second largest maize producer in Mozambique. Maize production descriptive statistics are given

³ Intensification is defined here as the increase in average inputs of labor or capital on cultivated land for the purpose of increasing the value of the output per unit area.

⁴ The “informal” marketing systems in the region, on which most small-scale farmers rely, are generally characterized by (a) spot market transactions with weak mechanisms for market-based risk management; (b) weak information systems for reporting local market conditions; (c) limited coordination between input delivery, farm finance, and crop sale, resulting in part from poorly functioning input credit systems, in which non-repayment remains a ubiquitous problem; and (d) small businesses with relatively little political influence or voice in the determination of regulations governing the agricultural sector. This contrasts markedly with formal sector firms, which have organized lobbies and are widely perceived as having a legitimate interest and voice in the determination of regulations governing agricultural markets.

in Table 2.1⁵. In the last decade Manica produced in average 161,187 metric tons of maize as indicated below.

Table 2.1 Maize Production (t) in Mozambique Descriptive Statistics (1992-2002).

Province	Mean	Standard deviation	Maximum	Minimum
Cabo Delgado	68,743	21,870	105,565	40,359
Niassa	139,080	35,455	178,633	79,481
Nampula	97,516	28,883	129,197	41,173
Zambezia	174,911	53,028	260,066	81,979
Tete	115,394	50,149	177,798	36,000
Manica	161,187	58,119	260,829	76,000
Sofala	75,962	44,399	195,333	27,842
Inhambane	58,583	24,269	104,466	22,936
Gaza	43,590	20,392	74,050	16,825
Maputo	29,050	13,577	57,305	8,031

Source: Calculated from SNAP/Aviso Previo (2002)

Several agronomic constraints lead to very low maize yields. Low soil fertility, Striga, weeds, termites and low yielding varieties are some of the major constraints leading to yields averaging 1 ton/ha.

2.4.2 Sorghum Production in Manica

Sorghum is produced in both high and low rainfall areas of Manica. The three districts surveyed here are in the high rainfall location. The drier northern districts of Barue, Macossa, and Tambara are the main sorghum and millet producers in the province. Manica produced on average 5,555 metric tons of sorghum per year in the last

⁵ Appendix C1 and C2 present maize and sorghum production in Manica for the period 1992-2002.

decade. The largest sorghum producer with annual production of 63,936 metric tons is Zambezia (Table 2.2).

Table 2.2 Sorghum Production (t) in Mozambique. Descriptive Statistics (1992-2002).

Province	Mean	Standard deviation	Maximum	Minimum
Cabo Delgado	16,999	14,486	49,910	6,800
Niassa	7,386	11,235	29,146	904
Nampula	34,054	25,352	83,933	13,987
Zambezia	63,936	27,123	95,405	19,724
Tete	6,084	12,675	31,115	17
Manica	5,555	11,392	30,708	75
Sofala	23,234	10,033	41,004	10,594
Inhambane	3,766	4,496	13,172	912
Gaza	10,625	7,648	24,543	1,981
Maputo	3,562	2,157	7,030	480

Source: Calculated from SNAP/Aviso Previo (2002)

2.5 Marketing

The maize trading in Manica is typical of many areas of Mozambique. Maize trading involves a great variety of markets, varying from near perfect competition in the larger urban markets where the daily selling and buying prices are known by stakeholders, to buyer-dominated situations in the remoter producing areas where buyer presence is occasional. Reflecting transaction and transport costs and the need for income at harvest, producers tend to sell considerably below prevailing retail prices in urban markets.

There is an increasing participation of farm household in the markets. While Benfica (1998) found only 33% of smallholder households selling food crops in Manica province, our survey indicated that for this prime agricultural region, in 2003, more than

70% of the farmers were involved in marketing food crops. This is not surprising since our target districts (Gondola, Manica and Sussundenga) are not only a prime cereal producer area but also a well connected region to consumer centers such as Beira, Tete and the southern cities of Maxixe, Xai-Xai and Maputo. About 20% of maize produced by the farm households interviewed was sold.

Field observations and farm household interviews found that maize marketing is generally carried out by the individual households and rather than by groups or associations. During maize surplus months following harvest (May, June, July), formal and informal traders will usually find maize readily available in the rural markets. As stocks dry up, however, traders are forced to travel into the more remote areas to find maize stored in homestead granaries and to find willing sellers during the lean months. Most of the informal buyers transport the grain to the deficit south specially to the urban areas of Maxixe, Xai-Xai and Maputo⁶.

2.6 Crop Utilization

Output utilization, by the household interviewed, varies by crop. Survey results indicated that on average 75% of maize is consumed and 20% sold for cash or exchanged for labor at weeding time and 5% donated to extended members of the family in need. Almost all the sorghum produced by the average household is consumed in the household. Only 5% is estimated to be sold (Table 2.3).

⁶ The peri-urban areas of Inhambane, Maxixe, Xai-Xai and Maputo, have very high demand for maize grain from within Mozambique because of taste preferences. Freshly ground maize using traditional maize pounders or grain mills is preferred to the imported maize meal from South Africa.

Table 2.3 Average Percentage of Crop Utilization in the Districts of Gondola, Manica and Sussundenga in Manica Province

Crop	Own consumption	Sales	Donation
Maize	75	20	5
Sorghum	90	5	5
Cowpeas	50	50	0
Beans	15	85	0
Cotton	0	100	0

Source: Survey data

Note: Donation refers to gratuitous transfer of part of the harvest to family members living outside the household (urban areas or areas affected by bad rainfall).

2.7 Farm Household Data

Farm household interviews were carried out in Manica, Gondola and Sussundenga districts in Manica, from February to April 2003. The farm household survey (Appendix B) included 56 households randomly chosen from both groups of participants and non-participants in on-farm varietal trials and demonstrations plots conducted by public research and extension services and funded by SG2000, PAN or PROAGRI. The interviews were administered to the household head (HH) because he/she is responsible for most of the decision making of the household. The participants were informed that their participation was voluntary and anonymous.

2.7.1. Household Characteristics

The survey data include household demographic characteristics, crop production, marketing, income sources, and expenditure. There are few differences among the households' characteristics across districts (Table 2.4). In 90% of the cases the household

head was male. The average age of the household head was 47 years. The level of education is low, averaging 3.5 years of schooling for all adults. There are 5 adults per household. The average area under cultivation is 5.5 ha. The dominant crop by area is maize. Other crops include sorghum, beans, cowpeas, cotton, tobacco, sunflower and horticultural crops in the lowlands.

Table 2.4 Average Household Characteristic, Crops and Livestock Ownership of Survey Farmers in 3 Districts of Manica Province, 2003

Household characteristics	Gondola	Manica	Sussundenga	Average
Age of Household Head (years)	47	47	46	46.6
Male headed household (%)	90	85	95	90
Education of HH (years)	3	6	3	3.5
Number of Adults	6	4	5	5.2
Total farm Area (ha)	4.4	6	6	5.4
Maize	2.5	3	2.5	2.6
Sorghum	0.3	0.1	0.4	0.3
Beans	0.3	0.2	0.3	0.3
Cowpeas	0.4	0.2	0.3	0.3
Cotton	0.2	0.3	0.5	0.3
Cattle (heads)	1	2	1	1.2
Goats (heads)	7	8	8	7.6
Fowls (units)	10	12	9	9.9
Fertilizer users (%)	10	20	15	14.0
Improved varieties users (%)	23	40	16	23.0
Market participation (%)	67	73	80	73.8

Source: Survey data

Most of the interviewed farmers in Manica district were former refugees in Zimbabwe for years during the Mozambican civil war. While in Zimbabwe most of these small scale farmers were introduced to more input intensive farming techniques. This may explain the higher percentage of input use than in the other two districts. Another possible reason is the lower costs of inputs in Zimbabwe. Interviewed farmers near the border said that they bought most of their inputs, in the neighboring city of Mutare in Zimbabwe, 7 km across the Machipanda border.

The average number of cattle in the sample is one (1) per household. Twenty percent of the households in the three districts owned at least a cow. A restocking program has been able to restore some cattle in Manica and Sussundenga. The low ownership of cattle explains the common use of manual instruments for most of the cultivation. Table 2.4 indicates that the average number of small ruminants (goats) is approximately 8 per household while in average each household owned 10 fowls. Twenty five percent of the interviewed farmers owned at least one goat and 75% of them owned at least one fowl.

2.7.2 Crop Production Technologies

Although the majority of the farmers still grow local varieties, there is a substantial use of inputs such as seeds of new cultivars. On average, twenty three percent said they used improved cultivars in the previous season (Table 2.4). The highest proportion of improved cultivar users were found in Manica district, with 40% using new maize cultivars, compared to 23% and 16% for Gondola and Sussundenga respectively.

Most of the new cultivars were open pollinated varieties (OPV's), which were being re-used.

Farmers obtain seeds from various sources. Sixty percent of the farmers using improved maize cultivars said that they have saved the seed from the previous crop, 25% received seed from government extension services or development programs, and 15% said they bought improved OPV from input shops. Some farmers, especially in the district of Manica, close to the border, bought maize hybrids and OPV seeds in the neighboring Zimbabwe.

The local varieties include a group of varieties that have been locally adapted or selected. The local varieties are obtained from other farmers and passed from generation to generation. The local varieties commonly used in the surveyed area include: Chimanica, La Posta, Kangere, Chinyamwana, Macolo and Chingenda. All local varieties are tall, long season maturity, with white large grain, good poundability and resistance to weevils. Improved cultivars include hybrids and OPVs. In Chapter 3 a detailed description of the most common varieties and hybrids is given. The most used improved maize OPV's are Matuba and Manica.

Soil fertility practices followed by farmers in Manica province include: fertilizer incorporation, fallowing, use of livestock manure (goats, cattle, chicken), crop rotation (beans/cowpeas and maize), incorporation of stover and grass/avoid burning of grass and intercropping. Fourteen percent of the household survey respondents confirmed use of inorganic fertilizer in the previous season. The highest proportion of fertilizer users were found in Manica district, with 20% of the interviewed farmers using fertilizers compared to 10 and 15% in the other two districts (Table 2.4).

2.7.3 Household Income

Agriculture (crops and livestock) is the most important source of livelihood for more than 85% of the farmers in Manica. Based on the survey data, the annual average household in Manica, has an income of MZM8, 094,000 (\$335). The district of Manica reported a much higher household income \$445 per year compared to \$320 and \$250 for Sussundenga and Gondola respectively (Uaiene, 2003). Households get their cash income from crop sales (food crops and cash crops), livestock sales, remittances and others (small enterprise activities such as retail trading, off-farm employment) (Table 2.5).

The highest share of income comes from crops (61%) including maize, beans, vegetables, cotton, tobacco and banana in Gondola. Crop and livestock incomes include sales and the value of home consumption at the farm producer's price. Off-farm income includes micro and small enterprises (MSE) and wage income (3%) and remittances (5%), transfer and donations and others (20%). Off-farm work includes manufacturing, trading and gathering. Participation in farm and non-farm labor markets although negligible is included in this category.

Most of the grain is sold at harvest when the prices are lowest. The household decision to sell at harvest when the prices are low is associated with a strong desire for cash to finance consumption which, includes paying wages, taxes, past bills and school fees, in the immediate post-harvest period (Arndt et al, 2001) rather than a physical inability to hold their own stocks.

Table 2.5 Average Income (US\$) per Household per District, Manica, 2003

Source	Districts			Average	%
	Gondola	Manica	Sussundenga		
Crops	\$165	\$270	\$187.5	\$204	61
Livestock	\$25	\$50	\$33	\$36	11
Off-farm work	\$8	\$15	\$8	\$10	3
Remittances	\$12	\$20	\$15	\$16	5
Others ^a	\$41	\$90	\$75	\$69	20
Total	\$250	\$445	\$320	\$335	100

Source: Survey data

^a “Others” include income from micro and small enterprises such as firewood gathering, sales of beverages, especially sorghum beer and retail trade
1 USD =MZM23,854 (IMF, 2004)

2.7.4 Household Expenditure

Household expenses vary with season in Manica. Farmers divide the year into three main seasons; harvest, post harvest and hungry period. The main harvest period laps from May-July, the post harvest is defined here as the period from harvest (August until December). The hungry period is the period late in the crop season before the following harvest.

Table 2.6 presents average household expenses at harvest for 2002, a normal year. Farmers are forced to sell their grain at harvest time due to pressing cash needs. These needs include clothing, loan repayment and household expenses for commodities produced outside the farm household, medical and school fees and social ceremonies, such as weddings and name ceremonies. Expenses in clothing for the family, which represents 24% of the total expenditure, occur at harvest when the crops are sold. The

expenses in clothing at harvest often represent implicit wages for family member labor during the crop season. Health expenses represent 13% of the total harvest expenses. Health expenses include payment to traditional healers. A substantial portion (24%) of harvest time cash expenditure is allocated to ceremonies such as weddings, baptisms, and name ceremonies.

Table 2.6 Cash Expenditure (US\$) at Harvest Time (May-July), Manica, 2002

Expenditure	District			Average	(%)
	Gondola	Manica	Sussundenga		
Food	\$15	\$20	\$16	\$17	19
Clothing	\$20	\$23	\$20	\$21	24
Health	\$10	\$12	\$11	\$11	13
School	\$2.50	\$2.40	\$2.50	\$2	2
Ceremonies	\$21	\$31	\$15	\$26	24
Loan repayment	\$10	\$12	\$10	\$10	13
Others ^b	\$8	\$4	\$2.50	\$2	5
Total	\$86	\$105	\$77	\$89	100

Source: Survey Data

^b “Others” include expenditures in housing, means of transport such as bicycles
1 USD =MZM23,854 (IMF, 2004)

Farmers involved in contracting farming (cotton, tobacco, sunflower) have to repay the inputs (seeds, fertilizers and pesticides) used at the harvest. Repayment of loans is required at harvest time (May-July). Input suppliers for maize production also expected the repayment to be made following the harvest. The repayment of loans is part of harvest time expenditure and presses the farmers to sell their crops at low prices even though they may be aware of price recovery later. This is an indication of a strong desire for cash

to finance consumption, which in the absence of rural saving and credit institutions make harvest income an important goal for the farm household.

The expenditure at any given season is expected to vary with the type of cropping season. In good cropping seasons farmers interviewed reported higher investments in item such as bicycles and house improvements.

Expenses at harvest time are so pressing that farmers sell part of their harvest even if that means paying higher prices later in the season to repurchase the food staples. A comparison of Table 2.6 and Table 2.7 clearly indicates the importance of harvest time income. Cash expenses in clothing, ceremonies, and loan repayment expenses are higher right after harvest than 6-7 months after harvest. Expenses in clothing which represent implicit wages to family members are higher (24%) just after harvest (Table 2.6) than they are 6 months after harvest (15.5%) as indicated in Table 2.7.

Table 2.7 Post harvest Cash Expenditure (\$) (August-December), Manica, 2002

Expenditure	District			Average	(%)
	Gondola	Manica	Sussundenga		
Food	\$40	\$35	\$29	\$35	45.0
Clothing	\$10	\$10	\$15	\$12	15.5
Health	\$10	\$12	\$11	\$11	14.0
Ceremonies	\$10	\$13	\$13	\$12	15.5
Others ^b	\$12	\$5	\$7	\$8	10.0
Total	\$82	\$75	\$75	\$77	100.0

Source: Survey Data

^b "Others" include expenditures in housing, means of transport such as bicycles
1 USD =MZM23,854 (IMF, 2004)

Farmers in Manica choose to satisfy their harvest time income requirements first and then to rely on purchases in the market to provide their food requirement latter. This is indicated by the large share of food expenditure in the period (August-December). The largest expenses in food occur 6-7 months after harvest. The average expenses in food can be as high as 45% of the total expenditure on that period as reported in Table 2.7. The share of food expenditure is still higher in the hungry period (just before the new harvest) since the household is unable to satisfy both harvest income and storage objectives.

2.7.5. Household food consumption

All farm households in the study area grow food crops as their food safety strategy. Maize and sorghum are stored in granaries “*celeiros*” for use during the year. Farmers’ estimates obtained from household interviews (Table 2.8) indicate that food stocks last on average 10 months in normal states of nature, 12 months in good rainfall years and 15 months in very good rainfall years⁷. In very bad and bad states of nature maize stocks last for less than 6 months leaving the household dependent on food donations, remittances and occasionally earnings from working off-farm.

⁷ The winter crop and cropping on the river basins help to reduce the food gap. The best farmers plant early maturing maize varieties which they call “two months” due to their short cycle. Horticultural crops (tomato, onion, garlic, cabbage) are also planted during the winter providing not only food for the household but also a source of cash.

Table 2.8 Average Maize and Sorghum Storage Time (months) by States of Nature in Manica

	Very Bad	Bad	Normal	Good	Very Good
Maize	3	5	10	12	15
Sorghum	4	6	10	12	15

Source: Survey data

The survey respondents consumed about 80% of their maize production, 95% of their sorghum and only 15% of their beans (Table 2.9). Most of the beans are sold for cash while very little sorghum enters the market.

Table 2.9 Maize and Sorghum Utilization (percentage per category)

	Own-consumption	Sales	Donation
Maize	78	20	2
Sorghum	95	0	5
Beans	15	85	-

Source: Survey data

All farmers interviewed set aside grain for own consumption. Like in the Sahel where income requirement are more pressing than subsistence goals (Abdoulaye and Sanders (2003), 2002; Vitale, 2001) farmers in Manica sell so much of their crops at harvest that in below normal rainfall years they are unable to set aside sufficient grain for subsistence. Hence, they have to buy this grain.

2.8 Conclusion

Farmers in Manica province obtain most of their food and cash from the crops they raise mainly maize, sorghum, cowpeas and beans. Household farm income comes primarily from crops of which maize plays a significant role. Crops, both own-consumption and sales, are responsible for a significant share of the total household's annual income. More than 90% of the crop sales occur immediately after harvest when the prices are at lowest point.

Household expenditure includes food, clothing, health, school fees, loan repayments and ceremonies. A significant share of household expenditures occurs immediately after harvest (55%) when the household has to repay loans, pay wages to family members and perform social ceremonies, while a higher share of expenses in the period 6 months after harvest is spent on food. This makes the farmer more vulnerable to receiving low prices for his or her grain sales in order to obtain the harvest income requirement. The farmers also have to pay higher prices for the same food staples later.

Two major concerns govern the household decision making in the district surveyed. Empirical evidence shows that the first one is the need for cash to buy goods and services not produced by the household at the harvest period. The strong desire for cash explains why farmers sell a large share of their grain at harvest only to buy back grain later in the season. The harvest income requirement reduces the household food availability requiring increased food purchases later in the year. The second is the ability to have on-farm food production to meet the farm household demand for food thus minimizing the market dependency.

CHAPTER III

MAIZE AND SORGHUM TECHNOLOGIES, PRICE VARIABILITY AND MARKETING STRATEGIES

3.1 Introduction

In general, a technology to be adopted has to satisfy three basic criteria: it has to provide a yield advantage, cost saving or both when compared to the currently used technologies, it has to be profitable and it has to fit into the farming system. In this chapter using the criteria of yield advantage and profitability we evaluate the best available maize and sorghum technologies for their yields and profitability. With programming models we will evaluate the third component, the fit into the farming system in Chapter 5.

3.2 Maize Technologies

Seed and fertilizer based technologies have been introduced to maize farmers in Manica through public and private extension services. Open pollinated varieties, hybrids, and fertilizer have been introduced by government extension and seed company demonstration plots as well as on on-farm trials. A number of farmers have had access to these new technologies through emergency programs or through development programs such as SG2000, PAN and others. Other technologies being promoted include

conservation tillage and herbicide use. Several white, open pollinated cultivars and hybrids developed by public and private institutions are available to farmers including quality protein maize (QPM), but the adoption of all of them is still limited.

Twenty three percent of the interviewed farmers in the three districts planted both traditional and an improved cultivar in the previous cropping season (2001/02) (Table 3.1). Of the districts interviewed, Manica district has the highest percentage of farmers who planted improved maize the previous cropping season (40%) while Sussundenga has the lowest (16%). Most of those who planted improved maize received the seed and fertilizer from development agencies such as SG2000 or from government programs such as PROAGRI. No single farmer interviewed planted only the improved cultivar. Farmers plant both traditional and new improved cultivars. The average area planted to an improved maize cultivar, among those planting the new cultivars was 0.5 ha while the traditional cultivars were planted by all on an average of 2.3 ha.

Table 3.1 Farmers Who Planted at Least One Improved Maize Cultivars in 2001/02

District	Number of HHs	HH using improved	% of users
Gondola	22	5	23
Manica	10	4	40
Sussundenga	25	4	16
Total	57	13	23

Source: survey data

Improved cultivars in the region are early, intermediate and late maturing cultivars. Early maturing cultivars such Matuba, are included in the farmer's

diversification portfolio as an insurance policy. Among the intermediate to late cultivars grown in Manica are the hybrid PANNAR 67 (PAN 67) and QPM Sussuma.

Fertilizers are not commonly used in the foodcrop sector in Manica. Most of the interviewed households said that the same land is repeatedly sown with the same crops, and they are aware of soil quality deterioration and the need of fertilizer to improve soil fertility. Fertilizer is, however, used primarily on cash crops such as cotton and tobacco, in which case the processors usually supply inputs on credit against the crop. The credit in these traditional cash crops is expected because the creditors (contractors) can be relatively sure of repayment, due to monopsonistic arrangements. The assurance of repayments allows the creditors to offer the farmers relatively favorable interest rates, thus explaining the greater use of capital in these enterprises relative to food crops.

Table 3.2 Farmers Who Used Fertilizer in the 2001/02 Cropping Season in the Survey Area

District	Number of HHs	HH using improved	% of users
Gondola	22	2	10
Manica	10	2	20
Sussundenga	25	4	15
Total	57	8	14

Source: survey data

Fourteen percent of the interviewed households used fertilizer in the previous season (Table 3.2). This type of technological intensification is higher in the study area

compared to the national average of only 7% of all farming households using inorganic fertilizer at all (<http://www.kyle.aem.cornell.edu/WorldBankJan04.htm>). The largest proportion of fertilizer users was observed in the district of Manica (20%) and the smallest in the district of Gondola (10%).

Interviewed farmers in the district of Manica have greater knowledge of different types of inorganic fertilizer and maize varieties than the farmers in the other two districts. Because depletion of soil fertility and the use of low yielding cultivars are major causes of low per capita grain production in Manica, and based on field observations, five maize activities are considered. The first consists of a traditional open pollinated variety without fertilizer which is common practice; the second consists of a new open pollinated maize cultivar Manica, developed by the National Agronomic Research Institute (INIA) without fertilizer. The cultivar Manica is widely available and well adapted to this agroecological region and farmers have shown increasing interest in the cultivar. The third is the maize cultivar Manica and a basal fertilizer. The fourth adds a side dressing fertilizer to the third. The fifth maize technology include the improved variety, fertilizer and a chemical control of weeds using glyphosate, before planting, commonly known as “no-till”⁸.

Major cash cost components of the new technologies are the seed and fertilizer costs. The maize seed of the improved cultivar was being sold, in February 2003, for MZM18,000/kg (\$0.75/kg) while the local cultivars, sold as grain for less than MZM2,400 (\$0.10) a 7:1 ratio. This high ratio might explain the reason why many

⁸ The basal fertilizer is the compound 12-24-12 and the dressing is Urea (46 N). One hundred (100) kilogram of each is applied per hectare. The compound is applied at planting and the side dressing is applied after weeding. The side dressing can be split in two applications.

farmers in Manica district buy their seeds from Zimbabwe where the same improved cultivar is less than \$0.50/kg.

The yield gap in both maize and sorghum is discussed in the following sections. Then the activities are compared using yields and simple budgeting for profitability with sales at different time periods.

3.2.1 The Maize Yield Gap

Considerable yield difference exists between farmers' yields and those obtained under controlled environments at research stations. The yields at research stations represent the yield frontier or the potential yield increase is the difference between these yields and those on farmers' field. These yield gaps indicate that substantial yield gains are available for most of the crops grown in Mozambique. The highest yields are obtained using improved cultivars and recommended levels of inorganic fertilizer. Using improved OPV or hybrids, maize yields up to 5,000 kg/ha have been obtained at Mozambican research stations (Denic, 2002).

On-farm yields using traditional technologies are very low. The average farm yield for maize in Manica is approximately 800 kg/ha (SPER-Manica, 2002). The yield gap between farmer's technology and the improved maize technology is thus of the magnitude of up to 4,200 kg/ha. This yield gap indicates considerable potential for maize yield improvements.

A large number of improved white maize cultivars and hybrids adapted to different agro-ecological environments are available for farmers. Table 3.3 lists some of

materials that are being sold in the retail market in Manica province. Consistently, these improved cultivars and hybrids have out yielded the traditional ones.

Table 3.3 Characteristics of Some Improved Maize Cultivars Grown in Manica

Variety	Type	Yield (t/ha)	Height ^a	Other characteristics ^b
SC 403	Hybrid	1-8	1.4	White hard dense grain, early maturing, drought-tolerant and streak and mottle tolerant
SC 405	Hybrid	4-8	1.3	White dent, early maturing, tolerant to grey leaf spot (GLS)
SC 407	Hybrid	4-8	1.4	White semi-flint, early maturing, resistant to maize streak (MSV) and tolerance to GLS
SC 501	Hybrid	3-6	1.5	White, dent, intermediate maturing
SC 709	Hybrid	8-13	1.7	Late white dent, similar to SR52
Semoc 1	OPV	1-7	1.4	White, flint, resistant to MSV and Down Mildew (DM)
LaPosta	OPV	1-4	2.0	A local variety, flint white, late-maturing, good resistance to DM and MSV
Matuba	OPV	1-5	1.5	Good resistance to DM, MSV, and weevil
PAN 3	OPV	1-5	1.4	Medium maturity, flint and hard grain, resistant to DM, MSV, weevil
PAN 67	Hybrid	4-9	1.4	Medium maturity, flint grain, drought tolerant, MSV tolerant and high-yielding

Source: SEED-CO (2003), PANNAR (2002) and INIA (1998)

^a refers to cob height in meters

^b early maturing ($x < 130$ days; intermediate $130 < x < 150$ days and late maturing $x > 150$ days)

Table 3.4 presents the descriptive statistics of the three most common cultivars in Manica. All cultivars were grown without fertilizer. The highest mean yield is obtained

with Sussuma with 2,509 kg/ha and the lowest reported average yield on farmers field is obtained with the local cultivar (1152 kg/ha).

Table 3.4 Descriptive Statistics of Maize On-farm Yield (kg/ha) Data (1999-2001) in Manica

	Local	Manica	Sussuma
Mean yield	1,152	2,382	2,509
Standard Error	300	376	294
Median	524	1,643	1,829
Standard deviation	1,239	2,061	1,713
Minimum	282	350	355
Maximum	4,264	7,903	5,627

Source: SPER -Manica (2002)

Without previous knowledge of individual attitudes to risk the identification of technologies likely to be adopted by risk-averse individuals can be conducted using stochastic dominance. Stochastic dominance as means of ranking risky alternatives is based on two observations of human behavior. First, most humans prefer to have more to having less. Second, they are risk averse. These observations of human behavior are measured by comparing cumulative distributions using two corresponding decision rules.

The first-degree stochastic dominance (FSD) assumes that individuals prefer more to less and states that an alternative is preferred if it provides a higher outcome at every level of probability. The preferred option has a probability distribution to the right of any other alternative distributions.

The second-degree stochastic dominance (SDSD) assumes that individuals are risk averse and focuses on the area under the cumulative distribution as a measure of

likelihood of an alternative to have low value outcomes. An alternative dominates if it has a smaller area under the distribution at every outcome level. Under stochastic dominance, strict specifications of a utility function are not needed in order to identify the preferred alternatives.

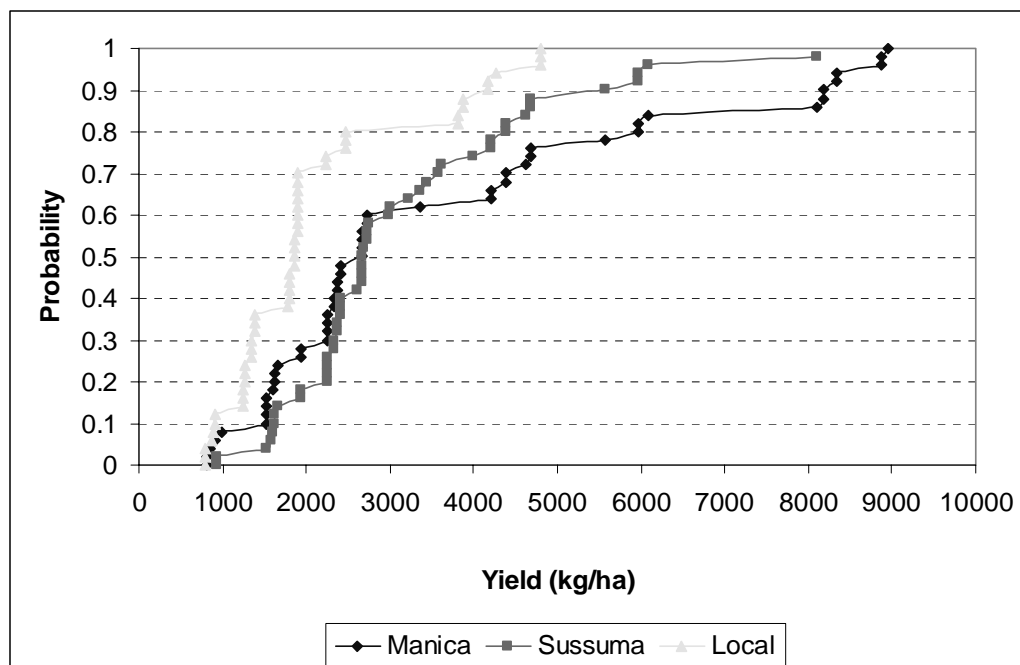


Figure 3.1 Cumulative Distributions of Maize Yield of 3 Varieties of Maize in Farmers' Fields in Manica Province, 1999-2002. Source: Author's computation from (SPER-Manica, 2002).

In this thesis stochastic dominance is used to analyze the performance of new improved maize technologies as compared to traditional technologies both in terms of agronomic yield and returns both with and without storage. On-farm trial data from 1999, 2000 and 2001 by the Manica Provincial Extension Services (SPER/SG2000) was used to determine the maize grain yield cumulative distributions. The maize grain yield

cumulative distributions show that the local variety is first order stochastically dominated by both Manica and Sussuma, two of the improved cultivars being disseminated in the districts of Gondola, Manica and Sussundenga. More than 70% of yields observed with the local cultivars is below 1500 kg/ha, while the yield can be as high as 3,500 kg/ha for the cultivar Manica and as high as 4000 kg/ha for Sussuma (Figure 3.1). Sussuma dominates Manica by the SDSD.

Farmers in Manica are partially adopting the early maturing maize cultivars as part of their portfolio strategy with their traditional long-season cultivars. During a field visit in Manica (Feb-April 2003), SEMOC and PANNAR, two of the seed companies operating in Manica, confirmed that small scale farmers were looking for early maturing cultivars (open pollinated or hybrids), especially for the winter cropping in the lowlands or irrigated land.

Development of seed markets in Manica has been facilitated by the introduction of small packs (1-5 kg) of maize seeds. Both seed companies (SEMOC and PANNAR) have devoted time and energy to devising and distributing fertilizer and pesticide packages to accompany improved seeds in small packs which greatly facilitates the acquisition of these inputs by the small farmers.

3.3 Sorghum Technologies

Three new sorghum cultivars were released in Mozambique in the past decade. The cultivars were developed by INIA through partnership with the Sorghum and Millet

Improvement Program (SMIP)⁹ which is managed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The cultivars released are Macia developed from SDS3220, Chokwe from ICSV112 and Mamonhe from ICRISAT's accession IS8511 originally from Uganda.

These new cultivars were developed for low rainfall agroecologies, which does not match with the plateau of Manica, especially the central districts of Gondola, Manica and Sussundenga. Early maturity that is critical for the drought-prone environments that cover much of southern and part of central Mozambique is not a good prototype for high rainfall areas such as the Manica plateau. As a result the new sorghum varieties show poor field performance when compared to the local variety. Table 3.5 presents the descriptive statistics of the 3 sorghum cultivars described above. There are no significant differences in mean yield between the local and the improved cultivar. Moreover, the improved cultivars present higher yield variability than the local cultivar. The average yield of on-farm trials for the improved cultivars varies between 918 kg/ha and 1,088 kg/ha (Table 3.5).

Table 3.5 Descriptive Statistics of Sorghum On-farm Yield (kg/ha) Data (1999-2001) in Manica

	Local	Macia	Chokwe
Mean yield	1,036	918	1,088
Standard Error	85	122	108
Median	1,050	750	1,217
Standard deviation	561	806	717
Maximum	2,500	3,500	2,345

Source: SPER -Manica (2002)

⁹ SMIP is a SADC program implemented by ICRISAT.

Figure 3.2, below, indicates that the new improved varieties had a higher probability of having lower yield outcomes than the traditional variety. In 32% of cases, the local sorghum variety had a higher yield than both Macia and Chokwe. The new cultivars of sorghum (Macia, Chokwe and Mamonhe)¹⁰ out yielded the local cultivar in 20% of the years when there was drought at the end of growing cycle (terminal drought).

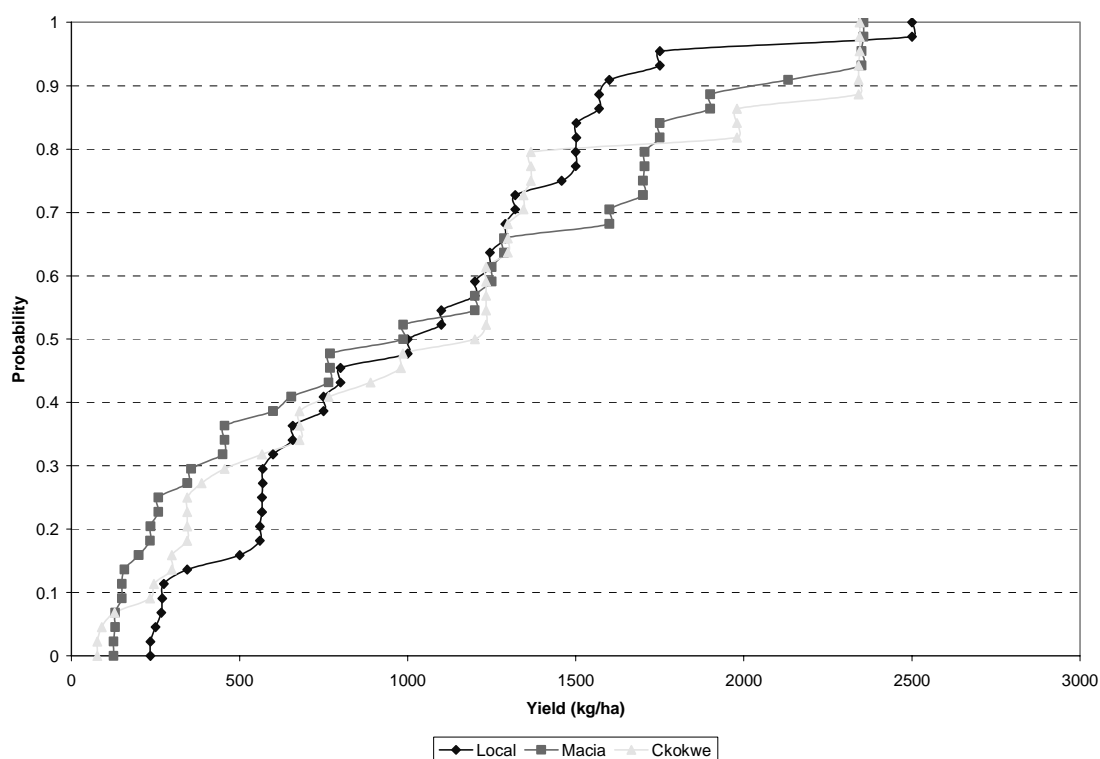


Figure 3.2 Cumulative Distributions of Maize Yield of 3 Varieties of Sorghum in Farmers' Fields in Manica Province, 1999-2002

Source: Calculated from the SPER-Manica on-farm data (2002)

¹⁰ These improved cultivars mature earlier than local cultivars, often before the end of the rainy season. This results in increased susceptibility to grain molds, greatly limiting the adoption of these cultivars. Traditional cultivars have traits such as lax panicle and gaping glumes which provides resistance to grain molds, strong photoperiod sensitivity, and resistance to water lodging.

The local cultivar dominates both improved cultivars by the second degree stochastic dominance. Under farmers' conditions none of these cultivars have good performance in the high rainfall area¹¹. These cultivars were developed and selected for drier areas and shorter rainfall periods. The growing period in the three districts (Gondola, Manica and Sussundenga) is above 5 months, which means that maturity of these varieties occurs during the rainy season. Late planting of the early cultivars has not been tested. Under such conditions, grain quality is lower due to fungi attack, which is facilitated by the compact panicle. Grain mold attack is often aggravated with a simultaneous attack by panicle feeding insects such as the sorghum midge (*Stenodiplosis sorghicola*) and sorghum head bug (*Eurystylus oldi*). Farmers involved in on-farm testing of the new early maturing sorghum cultivars indicated that these cultivars are constrained by birds, sorghum grain molds and insects. Birds are one of the most important pests of sorghum in Manica. In Manica, the most notorious species is *Quelea quelea* which is capable of inflicting heavy losses and causing economic damage.

For the reasons indicated above there is no suitable new sorghum technology for this region. Traditional technology includes the use of local cultivars which are typically tall (more than 3 meters in height), photo-sensitive, and these cultivars have a longer growing season than the improved ones. The local Guinea type cultivars have an open panicle, which dries quickly following any precipitation. This open panicle protects them against the fungi-insect complex as does their longer growing season. Traditional cultivars have very low levels of tannins. A high level of resistance to grain mold is one reason farmers in Manica remain attached to the traditional, guinea type cultivars. No

¹¹ The average rainfall in Manica is above 1000 mm. The rainfall period runs from October to April.

fertilization is used with the local cultivars. To determine how the proposed new technologies for maize and sorghum will affect the net income, partial budget analysis was used. Partial budget of traditional and new technologies are discussed in the next section.

3.4 Maize and Sorghum Partial Budgets

A necessary early step in developing and sustaining successful technology promotion and market development programs is profitability analysis. Higher yields are not enough to guarantee adoption of new cultivars or new technological packages. The profitability of new technologies is critical in the farmers' decision making process to adopt or not to adopt the new technologies.

A partial budget analysis for maize was developed taking into account several states of nature. Output prices vary not only with the state of nature (inter seasonal variation or between season variation) but also within each season (intra or within season variation). Detailed maize and sorghum, with and without fertilizer, partial budgets are presented in Appendix (B1-B4). Two different time periods are considered: sales at harvest and sales 6-8 months after harvest. The results indicate that under the current terms of trade, farmers do lose money in all states of nature considered if maize grain from the improved package is sold in June. For the traditional technology farmers lose only in the bad and normal years if sales are made in June.

Table 3.6 Partial Budget Analysis of Maize in Two Different Sale Periods in Manica

Technology and commercialization period	Traditional (July)	Traditional (December)	Improved Package (July)	Improved Package (Dec)
Expected Grain Production (kg/ha)	750	713*	2,750	2,613*
Grain price (\$/kg)	0.04	0.10	0.04	0.10
Variable Costs				
Seeds (\$/ha)			25.15	25.15
NPK (\$/ha)			41.92	41.92
Urea (\$/ha)			33.54	33.53
Additional labor (person-day/ha)			25.15	25.15
Storage cost	0	10.75	0	39.43
Total variable costs (\$/ha)		10.75	125.77	165.19
Gross income (\$/ha)	27.35	68.70	100.30	251.90
Net income (\$/ha)	27.35	57.95	-25.47	86.71
Marginal net benefit (\$/ha) from storage over traditional without storage		30.59	-52.82	59.35
Marginal rate of return (%) from storage	-	285	-	151

Source: Survey data

Notes: Seed cost; 20 kg/ha at \$0.84/kg of improved seed

New Package include, improved OPV and fertilizer

Price of fertilizer: \$0.42/ kg of NPK and \$0.34/kg of Urea. Grain price is average of June and December from SIMA (1998-2002).

The total cost of storage include the marginal cost of storage plus the opportunity cost of capital

1 USD=MZM23,854 (IMF, 2004)

* Yield discounted due to estimated 5% physical loss during the storage

Table 3.6 presents a partial budget for maize based on the expected yields. The expected yield is 750 kg/ha for traditional cultivar and 2,750 kg/ha for improved cultivar and fertilizer¹². The expected price, calculated over the period 1998 to 2002, at harvest is \$0.04/kg and the expected price in December, 6 months after harvest is \$0.10/kg. The new maize technology will use some additional labor for fertilization application and harvesting due to yield increase. Additional financial costs of new technology include seed and fertilizer.

The new maize package does not have an income advantage if the grain is sold at harvest when the prices are at their lowest point. The lack of income gains is due to unfavorable crop output/fertilizer price ratios. The failure to use fertilizer will lead to soil fertility depletion, thus the need for profitable packages which allow soil fertility replenishment.

Income gains are higher when improved maize and fertilizer package is introduced and grain is sold 6-8 months after harvest as shown in the partial budget (Table 3.6). The marginal rate of return for storage with traditional technologies is 285% and 151% for the improved package. Comparing these rates of returns with the interest rates of 36% per annum which farmers can expect to pay for borrowed capital (IMF,2004), it would be profitable for farmers to store maize grain and sell when prices recover for both traditional and improved packages. The shift to the new technologies requires substantial input purchases (seed and fertilizer). These do not pay off at the low

¹² It is assumed that a 5% loss occurs due to weight loss and insect and rodent damage if maize or sorghum is stored for 6 months. Storage cost is \$2.5 per ton per month (DNCI, 1999) or MZM60.00 per kilogram per month. The total storage cost is the product of the amount stored by the number of months and the cost of storage per kilogram per month plus the opportunity cost of capital. The interest rate is 3% per month.

harvest price. There is very high return for storage alone with traditional cultivars. The rate of return to storage are much lower with new technologies but the absolute gains are more than three times as high as with traditional technologies.

The mean net returns for traditional maize technology sold immediately after harvest was \$29.56 while the mean return for the improved maize package without storage is -\$9.01 indicating that harvest price, adopters of new maize technology lose money. Storage is profitable for both traditional and new technologies as indicated in Table 3.6 above. Figure 3.3 below gives the cumulative distribution of net return of traditional and improved technologies with storage. The storage of improved cultivars outperforms the traditional cultivars in 70% of the outcomes.

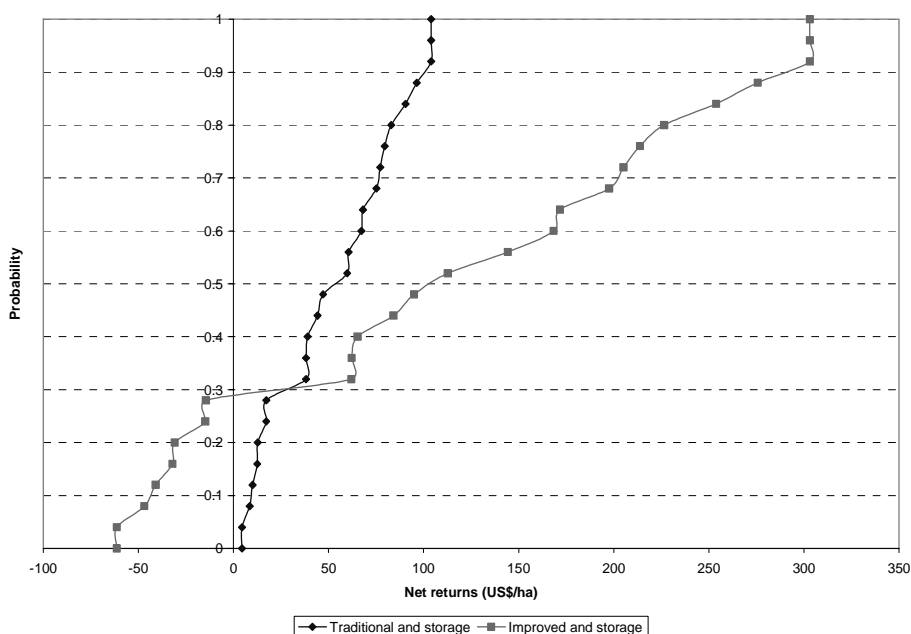


Figure 3.3 Net Returns of Traditional and Improved Maize Technologies w/ Storage
Source: Author's calculations

The analysis does not consider the opportunity cost of capital invested. Second, the analysis is done on per acre basis while risk analysis should be carried out in a whole

farm basis. In chapter 6 a whole farm model is used to analyze the optimal household portfolio.

There are no economic gains to the new sorghum technologies but there are gains to storage of the traditional sorghum (Table 3.7). Low yields of the new sorghums and low within year price variation in sorghum may explain why even with storage for the new cultivar, there are no economic gains. The marginal rate of return for storage is 53% with the traditional cultivar.

Table 3.7 Partial Budget Analysis of Sorghum in Two Different Sale Periods in Manica

Technology commercialization period	Traditional (July)	Traditional (December)
Expected Grain Production (kg/ha)	450	428*
Grain price (\$/kg)	0.08	0.10
Storage cost (\$)	0	4.45
Total variable costs (\$/ha)	0	4.45
Gross income (\$/ha)	36	42.8
Net income	36	38.35
Marginal net benefit (\$/ha) from storage		2.35
Marginal rate of return (%) over storage		53

Source: Survey data

* Indicates 5% loss due to weight and insect damage. Sorghum grain price is the mean of 5 marketing years.

1 USD=MZM23,854 (IMF, 2004)

Both partial budgets clearly indicate the importance of storage for both maize and sorghum. New and traditional maize cultivar-fertilizer based technologies become profitable with new marketing strategies. Grain sales in July, after harvest, result in net

income loss as the prices are at their lowest point. New sorghum technologies are never profitable not even with storage.

The current farming system in Manica is one in which there is very little use of improved cultivars and other modern inputs, especially fertilizers. As the partial budgets have shown, for maize, higher returns can be obtained with the introduction of cultivar-fertilizer based technologies, but they depend upon simultaneous adoption of new marketing strategies. None of the new technology sorghum activities are profitable. However, there is 40% return to storage on later sale of the traditional sorghum. In the analytical chapters the combinations of new technologies and the new marketing strategies will be evaluated in a household programming model.

3.5 Price Variability and Marketing Strategies

Agriculture production is seasonal by nature and varies between seasons, which leads to within and between seasonal price variability. Maize is the cereal most affected by price variation in Mozambique as sorghum rarely is marketed beyond the production sites. With the current liberalization of prices, farmers face two types of price variability, the seasonal variation, with low prices at harvest and the between years variations with a price collapse in good years. The next sections will illustrate these two types of price variation.

3.5.1 Within Season Maize Price Variation.

Figure 3.4 exhibits real maize prices (2003 as a base year) received by the producer in Chimoio from January 1999 to April 2003. The lowest seasonal maize

producer' price is observed in (April, May and June). The troughs coincide with harvest period, while the highest price is observed 6-8 months after harvesting (December, January and February).

Table 3.8 Maize Grain June Price Increases in Percentage of Nominal Price

Year	1999	2000	2001	2002
Between June and November	65	64	212	136
Between June and December	107	104	227	133
Between June and January	--	148	87	386

Source: Compiled by the author on the basis of SIMA (2003)

The increase of prices during the year has been different from year to year (Table 3.8 and Figure 3.5). Price variation from June to November ranged from 64% in 2000 to 212% in 2001 and from 104% to as high as 227% from June 2000 to December 2001. The biggest increase, 386%, was observed in a bad year, between June of 2001 and January of 2002.

The seasonality in prices of grain is principally determined by the farmers selling immediately after harvest to meet needs, such as school fees, medicines, and payment of debt especially inputs such as seeds, fertilizer and pesticides.

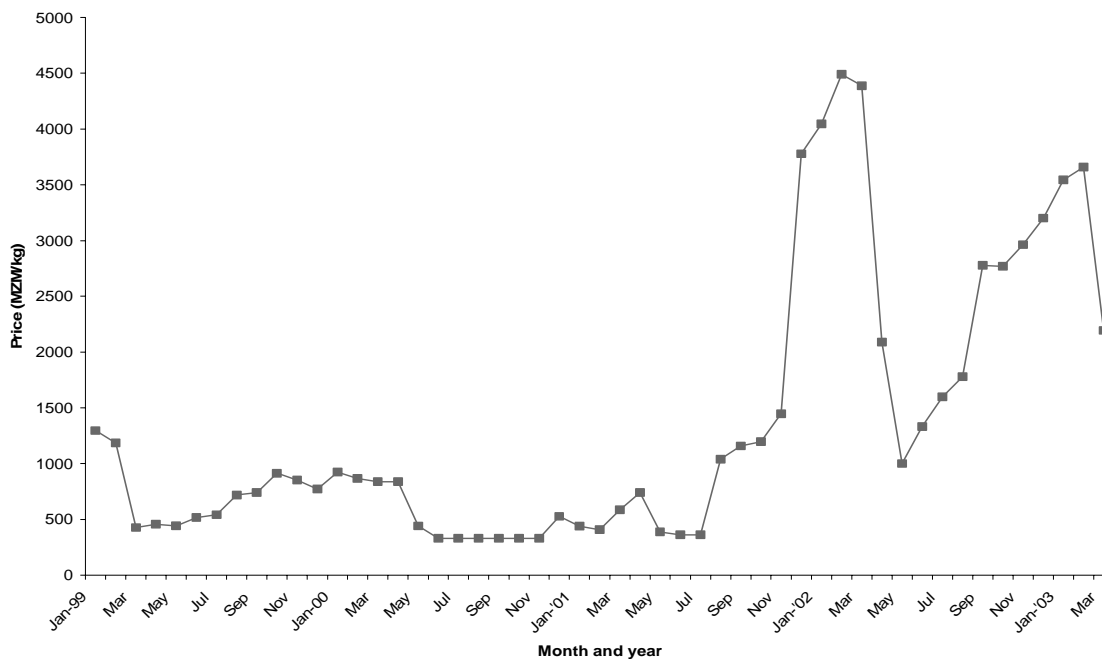


Figure 3.4. Maize Real Price Deflated by CPI (INE, 2004) in Chimoio
Source: SIMA(2003)

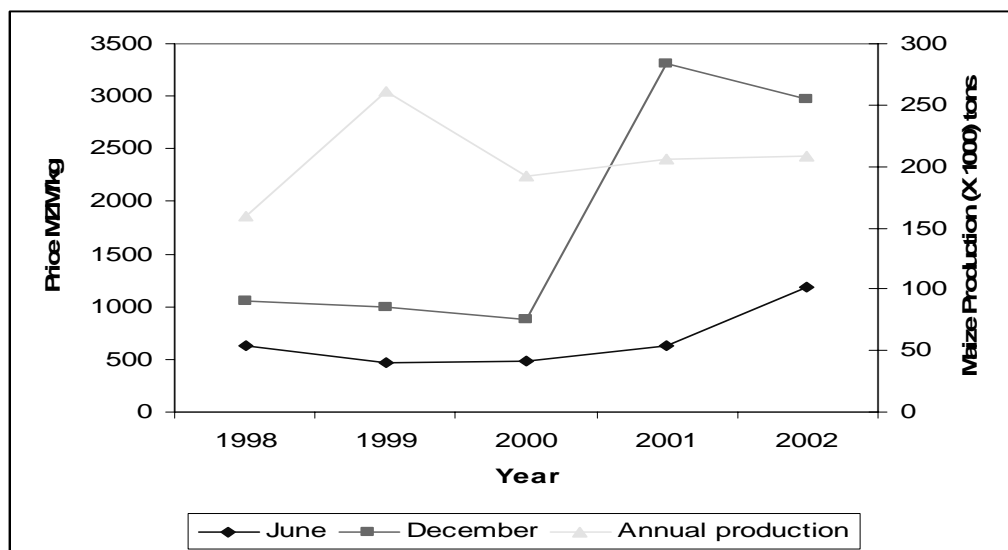


Figure 3.5 Maize Real Average Prices in June and December and Production in Manica.

Source: SIMA(2003)

3.5.2 Between Year Maize Price Variability

There is significant maize producer' price variability between years in Manica. During the 1999 and 2000 marketing seasons, Manica observed the lowest prices of the period in analysis (1995-2003) due to very good local and regional harvests. With the good weather, Manica had in the cropping season 1998/99, a record high of 260,829 ton of maize was produced, a 64% increase compared to the previous year. This resulted in price collapse of 33% in 1999 and 26% in 2000 (both compared with 1998 prices) (Table 3.9).

Table 3.9 Maize Real Prices (MZM/kg) Adjusted to 2003 in Chimoio (1995-2002)

Year	Mean	Variation (%)
1995	1730	66
1996	1248	20
1997	918	-12
1998	1042	0
1999	697	-33
2000	765	-26
2001	1493	43
2002	2424	133

Source: Calculated from SIMA (2003)

1USD = MZM 23,854 (IMF,2004). Price variation with base year (1998)

Maize price collapses with increased supply in good and very good years. Increased supply of this basic staple can result from good weather and is aggravated by crop intensification. The price collapse is explained by the inelastic demand for the food staple. Although consumers benefit from low food prices, producers are hurt except for the early adopters. Technological change reduces per output unit costs so the early

adopters of technology usually benefit. The degree to which farmers and consumers gain or lose is a function of price elasticity of demand, the percentage change in demand as a result of a one percentage change in price of output.

Price collapses are a disincentive for farmers using modern inputs. To respond to the price collapse from good weather and/or rapid diffusion of technological change, new markets would shift the demand to the right. Demand expansion alternatives include food agro-processing, namely the production of beer malt, starch and flour, processed foods, and animal feed. A significant change in sorghum or maize demand would shift the prices upward, thus increasing farmers' income (Vitale, 2001).

A longer run phenomenon than the increasing demand for processed foods is the structural shift in consumption patterns with rising incomes. Those consumers with higher income have higher propensity to consume animal products, fruits and vegetables and lower propensity to consume food grains. The demand for feed grains will increase rapidly as the demand for animal products increases.

Demand expansion reduces the price collapse due to increased supply in good and very good states especially as new technology is being diffused. The growing poultry industry will expand demand for feed grain. As the economy and income in Manica grow, more animal products are expected in the diet with a resulting expansion in the demand for feed.

The high between season price variation observed between 2000 and 2001 can be explained by the floods that devastated the region in the cropping season 2000/01 reducing the supply of maize.

In the next section potential marketing strategies that can reduce the intra-seasonal and inter-seasonal price variability are discussed. This is the focus of this thesis. The main hypothesis is thus that by giving producers higher prices via marketing strategies technology introduction will be accelerated, and farmers' incomes thereby increased.

3.6 Marketing Strategies

Marketing strategies can help increase expected profit and reduce the riskiness of higher input technologies. Several strategies to increase expected profits are discussed in the following sections.

3.6.1 Strategies to Moderate the Effects of Harvest Price Collapse

Lacking liquidity and sometimes market information, the small scale farmers sell their output at harvest. They do so, in order to be able to repay loans and to obtain cash for other household expenses (non-farm goods and services), to repay labor, loans and for ceremonies.

The seasonal price variation constitutes a constraint and an opportunity for farmers. Thus far, farmers have not been able to consistently exploit the opportunity offered by the seasonal price swings. Traders, both formal and informal are the principal beneficiaries from the seasonal price variation as they buy grain at low prices just after harvest (April to June) store it and sell it later, sometimes back to farmers at higher prices.

If the farmers were able to sell later, they would be able to receive a higher price for their grain¹³ and incomes would improve. This would be an incentive to intensify their maize production. In order to be able to sell later, farmers need alternative financial sources to satisfy their immediate needs for the repayment of loans, expenses in commodities not produced on-farm (salt, dried fish, sugar), medical and school fees among others as indicated earlier.

A marketing strategy to be tested in this study is one in which a farmer stores his or her grain for at least 6 months and sells it when prices recover. The farmer receives credit using the grain as collateral. This is the inventory credit discussed in the next section.

Inventory credit is not yet a common practice in Mozambique but a significant number of marketing associations are operating under the auspices of several NGO's. These marketing associations are pooling and selling their grain in most cases at harvest time. With full fledged associations, there would be scope for the inventory credit based on village storage systems.

Farmers are well aware of seasonal price variation. In a recent farm household interviews farmers gave expected prices of maize grain in three different periods: at harvest, post harvest (6 months after harvest) and at the hungry period which is the period 2-3 months before the harvest. Table 3.10 indicates farmers' expectations of farm gate maize price for the cropping season 2002/03. Expected output prices in the period July-November were 38% above prices at the beginning of harvest in April 2002.

¹³ The average price in Manica for June is MZM870/kg and MZM1950/kg for December over the period 1988-2002.

Table 3.10 Observed and Farmers' Expected Maize Producer's Price in the Cropping Season 2002/03 (MZM/kg)

District	April 2003 (Observed)	Expected Post harvest (July-Nov)	Expected At hungry period Dec 03-Feb 04
Gondola	1830	2500	2750
Manica	1800	2550	2650
Sussundenga	1845	2550	2745
Average	1825	2533	2715

Source: Survey results

1 USD =MZM23,854 (IMF, 2004)

Note: the cropping season 2002/03 was a bad year for Manica farmers due to bad rainfall distribution

Table 3.11 Expected Maize Prices (MZM/kg) from Different States of Nature

State of nature	at harvest	6 months later	Difference	(%)
Very Bad (0.05)	2100	3500	1400	67
Bad (0.2)	1680	2600	920	55
Normal (0.4)	1260	2000	740	58
Good (0.3)	1000	1500	500	50
Very Good (0.05)	960	1250	290	30
Weighted Mean	1293	2008	715	55

Source: SIMA (2003)

1 USD =MZM23,854 (IMF, 2004)

Note: Values in parenthesis are probabilities for each state of nature

Expected maize prices at harvest and six months after harvest in different states of nature are presented in Table 3.11. The highest price increase is expected in very bad

states of nature while the smallest are expected in very good states of nature. Table 3.11 indicates that in very bad state of nature, the price of maize is expected to increase between harvest and 6 months after harvest by approximately 67%. Whereas, in very good state of nature only 30% price increases between the harvest and the lean period are expected.

If farmers are to benefit from cereal sales, they need to store and sell at least part of their harvest a few months later when the price recovers. But farmers can only afford to store if their cash needs can be provided until the price recovery. The grain stored can be used as collateral to borrow money for their immediate needs. This is called inventory credit which is discussed below.

3.6.1.1 Inventory Credit

Inventory credit is one way of increasing returns to farmers making their activities more profitable. As argued by Coulter and Shepard (1995) obtaining finance against stocks of a wide range of products held in bonded warehouses is common in much of the world. Inventory credit for agricultural produce is widely used in Latin American countries and in some Asian countries (Coulter and Shepard, 1995). Ouendeba et al. (2003) report the existence of several Warrantage or government and non-government run Inventory Credit programs all over the Sahel for different food crops.

Holding stocks of cereal grain after harvesting would help smooth the variation in price. Holding stocks to sell when the price is favorable, can be a good marketing strategy if the combined costs of holding stocks (the opportunity cost of capital) plus the bearing of risk is lower than the expected gains in increased price. Calculated from the

SIMA, the Marketing Information System of the Ministry of Agriculture and Rural Development the five years average price of white grain of maize is 870 Mt/kg in June (1998-2002) in Chimoio. The average in December for the same period is 124% higher. This is a substantial price increase that is not being exploited by local farmers.

Assuming that farmer's associations can pool together their grain and using the mean prices of June and December for the 5 years period observed, Table 3.12 indicates that inventory credit is a worthwhile arrangement to increase farmer's income.

Table 3.12 Anticipated Incomes (US\$) for Farmers' Associations if Maize Grain is Stored and Sold 8 Months After Harvest

Price Increase	Unit	Medium	High	low
Quantity in kg	Kg	20000	20000	20000
Price at harvesting time	\$/kg	0.04	0.04	0.04
Estimated price increase	%	141	200	80
Price eight months later	\$/kg	0.09	0.11	0.07
Income	\$	1757.94	2188.31	1312.99
Income at harvest	\$	729.44	729.44	729.44
Loan (75%) of estimated harvest income	\$	547.08	547.08	547.08
Interest (3%)	\$	131.30	131.30	131.30
Commission (2%)	\$	10.94	10.94	10.94
Total credit costs	\$	142.24	142.24	142.24
Storage fee	\$	321.96	321.96	321.96
Handling fee	\$	60.37	60.37	60.37
Transport cost	\$	419.22	419.22	419.22
Total costs	\$	943.78	943.78	943.78
Net margins	\$	814.16	1244.53	369.20
Net margins per kg	\$	0.04	0.06	0.02
Additional revenue 8 months later	\$	84.72	515.09	-360.23

Sources: Survey data , SIMA (2003) and PAMA (2003). 1 USD =MZM23,854

With the costs of storage, transport, handling, interest rate and commissions, the net margins per kg are higher than the price at harvest time. This is an indication that inventory credit could be a viable business. A loan of up to 75% of output value, interest rate of 3% a month as practiced by SG2000 and a commission of 2% were assumed.

Sensitivity analyses are conducted using three levels of price increase, low, medium and high which occur with probability of 0.35; 0.18 and 0.13 respectively. The price ranges from MZM 1,566/kg (\$0.077/kg) to MZM2,097/kg (\$0.087/kg). The results of the sensitivity analysis indicate that the increase in price should be 129%, corresponding to 1,996 MZM/kg (\$0.08/kg) to break-even. The expected price 8 months after harvest is well beyond the break-even price indicated here, making it easy to increase farmer's income by selling at a later stage.

The additional revenue of selling 8 months after harvest time varies from a loss of MZM 429/kg to a gain of MZM614/kg (\$-0.02/kg to \$0.03/kg). At a price increase of less than 80%, which occurs with probability of 0.39, there is no additional benefit from inventory credit but there are large gains over selling just after harvest if price increase is high or medium. If such a scheme can be successfully implemented, farmers would have extra income and thus fewer liquidity constraints next year, which is a big incentive for dynamic adoption of new technologies. The following programming section (Chapter 6) will evaluate the impacts of this type of program upon technology use and farmers' incomes.

Inventory credit schemes are not common in Mozambique but the Agricultural Market Support Program, also known as PAMA as well as several NGO's have programs to enhance rural financial services. Several of these have shown interest in rural inventory

credit schemes. If these initiatives are successful, they would enable small farmers associations to do grain storage thereby benefiting from the higher seasonal price. Inventory credit will be simulated in the Manica average farm household model to capture its contribution to farm income and the interaction of inventory credit with new technology introduction.

3.6.2 Demand Expansion

The variability in white maize harvests is one of the reasons for annual price variation. The price collapses with a good harvest while there is a dramatic increase with poor harvests. The substantial price variation is a result of inelastic demand for this staple food. The inelasticity of price results from the fact that after all those with money buy as much grain as they want to eat, there are few or no alternative uses but many still trying to sell so prices collapse.

Those with sufficient incomes to buy maize and those producing can only eat/use so much. The reduction of the price collapse in good rainfall years can be achieved if demand can be expanded. Interventions to moderate price collapse in good and very good states of nature include new cereal uses and agroprocessing. The combined effect of these strategies is expected to have an effect on relative output prices shifting the demand curve and/or making it more elastic with respect to price.

Food and feed agroprocessing especially for poultry are likely to be a contributor for high maize demand. The impact of such domestic maize market expansion into processed foods and feeds can result in the moderation of harvest price collapse in good

and very good states of nature. The model was run assuming that the prices at harvest in good and very good states of nature will not fall below their normal year levels.

White maize is the preferred grain throughout the SADC¹⁴ region as food staple. Expansion of the role of maize and sorghum beyond its use as a food staple is a way of increasing maize and sorghum demand. The expansion in demand for these cereals would be beneficial for small scale farmers in reducing the price collapse in very good years, and to moderate the effects of rapid technological change on prices.

Both maize and sorghum have substantial potential for increases in utilization. Also, new unconventional products can promote maize demand and sorghum commercialization in Mozambique. Maize is already industrially processed but sorghum is not¹⁵.

ICRISAT is trying to promote utilization in various forms – ready-made sorghum porridge mixes, sorghum-based malt for breweries, sorghum-wheat composite flour for bakeries, and now pop sorghum (SATrends, 2002). These initiatives will need to be extended to maize based farming systems such as Manica with the introduction of new cultivars designed for specific markets. Expanding demand for grain will help moderate the price differential between good and very good and normal cropping years.

¹⁴ SADC is the Southern Africa Development Community and it is made of the following countries: Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

¹⁵ Sorghum used for agro-processing into meals, flours, breakfast foods, energy drinks and snack foods is concentrated in South Africa, Zimbabwe and Botswana. The expansion of sorghum production and productivity in Mozambique depends upon the development of new end uses for sorghum.

3.6.3 Role of Government in Price Variability

Mozambique has been a principal food aid recipient country for over two decades. This food aid is often concentrated where there are crop failures but can quickly move out of those affected areas and depress the farm gate prices in other regions. In Mozambique in 2002-03, the Southern provinces and part of the central provinces, crop production especially maize was hit by a drought leaving more than 650,000 people at risk of hunger (AIM, July 28). To minimize the risk of starvation the Government of Japan donated to Mozambique \$4.2 million worth of rice to be distributed through the normal commercial channels (AIM, July 28,2003). The importation of rice depresses maize prices as the two cereals are substitutes. Depressed maize prices will depress farmer's income and discourage input purchases and investment in agriculture.

In the long run technological change lowers costs so price can come down and benefit both consumers and producers. In short run with annual and between year price collapses and governments bringing down prices in bad rainfall years, then when will farmers profit from new technologies?

Reversing the current low food price policy will lead to an increase in producer's maize price. In chapter 6, using a programming model, we study the effect of reversing the policy by assuming a price increase of 40% in bad years from the normal price. This is a moderation of the usual public policy effect of depressing the price in bad rainfall years.

Food aid, if not carefully targeted, can contribute to depress farmers' output prices. The price collapse can be caused directly by increase in supply of the cereal or its substitute. Elimination of price collapse in bad and very good states and moderation of

inter-seasonal price variability would result in a significant increase in the profitability of the cereal technologies. Increase in profitability is expected to result in increased liquidity, more intensification, and increased farmers' income. This will be tested in chapter 6.

3.7 Conclusion

This chapter has shown that significant yield gaps exist between current traditional technologies and the new maize cultivar and fertilizer based technologies. Large yield gains can be obtained with the introduction of improved maize cultivars combined with fertilization. With average yields of traditional maize technologies, which consists of local varieties without fertilization with yields below 1 ton/ha, the yield gap between the traditional technologies and the improved one on the experiment station, can be as high as 4,200 kg/ha.

There is no improved new sorghum technology adapted for the region. The new sorghum cultivars were developed for drought prone areas rather than for regions with good rainfall such as Manica. The earliness and compact head of the new sorghum cultivars do not fit well in the farming systems of the study area. Both sorghum cultivars Macia and Chokwe are early maturing varieties and they suffer from molds and head bud complex especially under the relatively long season and extended rains in Manica.

The yield advantage obtained by the use of new maize packages comes with substantial investments in inputs. The shift to new technologies, requires substantial input purchases, and does not pay off at the low harvest prices. In contrast, partial crop budgets indicate that the marginal rate of return over storage is as high as 188% if maize grain can

be stored and sold in December. In contrast if maize is sold at current harvest output prices, new maize technologies do not provide sufficient marginal gains to give incentives to farmers to adopt them. However, at the prices six month later, it is profitable to introduce the new maize technologies.

With sorghum there are no economic gains to the new technologies but there are still gains to storage of traditional cultivars. Partial budgets clearly indicate the importance of marketing for both traditional and new maize cultivars and for traditional sorghum.

Three marketing strategies were discussed in this section: inventory credit, expansion of maize demand and a government change in the handling of food aid. All marketing strategies aim at increasing the producer's price and consequently increasing farmer's income. Simulations indicate that there are large potential profits from the combination of new maize technology and storage. Moderation of price collapses hence increased expected prices can also be achieved through the reduction of the public policy of depressing the price in bad rainfall years. Similarly, demand expansion can moderate the good rainfall year price collapse.

Because partial budgeting used in this chapter is unable to reflect more complex farmer's objectives, a whole farm household model using mathematical programming is used to evaluate the fit of the new technologies with and without new marketing strategies into the farmers' activities. Chapter IV presents the conceptual and empirical framework of the model to be used.

CHAPTER IV

THE EMPIRICAL MODEL

4.1 Introduction

The objective of this chapter is to present an empirical model of farm household decision making calibrated to data from farm interviews in Manica. The conceptual framework is similar to the state contingent approach by Chambers and Quiggin (2000), and Rasmussen (2003). The model analyzes farm household investment decisions given the household goals and resource availability. New activity emphasis will be given to maize as sorghum technology has still to be developed for the higher rainfall region as indicated in the previous chapter. A whole farm programming model is a better tool for farm decision making than the partial budget and the stochastic dominance analysis presented in chapter 3.

The three most important factors in farmer decision making considered here are: the household harvest income requirement, the food subsistence objective and liquidity requirements. These factors are expected to be of principal importance in farmers' decision making about new technologies.

4.2 Household Decision Making

In this thesis, a household is defined as all persons sharing their meals. Farm households derive their livelihood mainly from agriculture, utilize almost exclusively family labor and very little capital in agricultural production and they farm relatively small areas¹⁶.

Two major concerns govern the household decision making in the district surveyed. Empirical evidence shows that the first one is the ability to have on-farm food production to meet the farm household demand for food thus reducing the market dependency. The food requirement will be expressed in terms of minimum caloric and protein requirement as given by FAO. The second is the need for cash to pay for agricultural family labor, buy goods and services not produced by the household and repayment of loans at the harvest period. These two goals are modeled here as being lexicographic in nature.

An important constraint in the household decision making is liquidity. Liquidity is crucial in order to pay for the increased input use associated with new technologies. The necessary liquidity for the input purchases is assumed to be generated internally within the household.

Interviews conducted in Feb-Apr 2003 indicated that both production and price risks were a major concern for farmers. The farmer risk strategy is handled in the model by the inclusion of harvest income and food subsistence goals. Once farmers take care of their subsistence food requirements and their income objective, they have handled their principal risks and can then maximize incomes.

¹⁶ The recent Agricultural Census in Mozambique, CAP (2000) found that more than 80% of farmers cultivate areas below 2.5 hectares. They also utilize communal areas for grazing.

4.3 Farmers Objectives

Direct objective representation is used in this work instead of the more traditional expected-utility and mean variance approaches, which as Chambers and Quiggin (2004) argue may be unrealistic. The farmers approach of handling risk is obtained directly from the farmers and thus easier to verify than the traditional approaches. Farmer interviews indicate that two major goals are considered in the household decision making: the satisfaction of harvest income objective and the minimum food consumption target. The importance of harvest time income seems to be even more important than setting aside subsistence food as indicated by food sales even in bad years. These two goals should be satisfied in each state of nature, except in the very bad one when food aid is expected. So the very bad state of nature is excluded from consideration in the calculation of the expected yield distributions. Both goals are part of the rural household risk management strategies. Similar approaches were used by Vitale (2001) and Abdoulaye (2002) in Mali and Niger respectively.

The objective function to be maximized over the states of nature is the expected income from post harvest sales¹⁷. Before selling for profits, farmers need to satisfy their harvest income requirements and own-food consumption goals.

4.3.1 Income at Harvest

A substantial amount of income at harvest is used for in-kind (clothing) payment of family labor, loan repayments, medical expenses and social ceremonies as documented in Table 2.6. Having enough cash income at harvesting is more pressing than putting aside

¹⁷ Total farm household income includes also fixed non-crop income.

sufficient food such that in some years the household has to repurchase food. Because harvest income goal is important in meeting the farmers' pressing requirement it is directly represented in the model as one of the farm household objectives. The income is state of nature contingent as it is the product of output contingent prices and output contingent yields. The output and output prices tend to be negatively correlated.

The main source of cash for farm households interviewed is the sales of a fraction of their crops. It is estimated that about 20% of maize produced by the farm households interviewed is sold (Table 4.1). Cash income is obtained not only from food crops but from cash crops (banana, tobacco, cotton, yam, beans and vegetables) and from animal sales¹⁸.

Table 4.1 Percentage of Quantity Sold of Selected Crops in each Period in Normal State of Nature

Crop	At harvest	Post harvest
Maize	90	10
Sorghum	0	0
Beans	100	0
Cotton	100	0

Source: Survey data

In the absence of pool market systems operated by cooperatives or associations (storing, selling and utilizing market power), hedging on the futures and options markets, the smallholder farmers, unlike farmers in more developed countries lack liquidity and

¹⁸ The contribution of off farm agricultural labor to the household income is very little probably due to the lack of landless labor and very few rural enterprises. Remittances as source of income for the household were fraction of the total income and variable (USD\$0.00-US\$84.00). Only 16% of the respondents declared that they have received remittances from relatives.

market information and they felt pressure to sell at harvest due to a number of debts and financial commitments including the payment of their own family labor. Farmers interviewed are willing to form groups and pool and store their grain and sell it when prices are higher.

Marketable surplus of maize and beans as well as all the cotton is sold following harvest to meet the cash needs for goods and services not produced on the farm. Maize contrary to sorghum is often used as cash crop. Most of the maize grain sales occur just after harvest when the formal and informal buyers are more active. With exception of small stocks (chicken, ducks) livestock is sold in cases of emergency as animals are commonly seen as savings.

One of the harvest income needs reported by farmers involved in programs such as SG2000 or with cash crops such as tobacco and cotton was to repay their debts. The payments of these obligations is made at harvest time and this is costly since the prices are at their lowest prices, making in some cases the participation in such programs not profitable as indicated in the maize and sorghum partial budgets (Appendix A1-A4)¹⁹. Table 4.2 presents harvest time output state-contingent price. With high yields (good states of nature), prices are low so that more crops have to be sold to achieve the target harvest income objective. Higher prices corresponds to bad states of nature, which indicates bad harvests and thus achieving harvest income impacts greatly on the food consumption objective.

¹⁹ Adding to the fact that the prices are low at harvest is the fact that farmers under such programs do not have insurance against crop failure which will affect their capacity to repay loans (Binswager and Rosenzweig, 1986).

Farm survey data indicates that the average household in the study area spent MZM2, 146,000 (\$89) at harvest in 2002, a year that was considered by the farmers a normal cropping season (Table 2.5). This represents 27% of the average household total annual income, as estimated by the survey. This is the amount used in the model as the minimum income requirement at harvest.

Table 4.2. Harvest Prices (MZM/kg) of Maize, Sorghum and Beans Chimoio (2003)

Crops\State	Very bad	Bad	Normal	Good	Very Good
Maize	2,100	1,680	1,200	1,000	960
Sorghum	1,400	1,200	1,000	900	850
Beans	8,625	8,500	8,000	7,900	7,500
Cowpeas	3,000	2,750	2,500	2,250	2,000

Source: Computed from May and June SIMA prices. Sorghum prices are from SIMAP-Manica.

1 USD =MZM23,854 (IMF, 2004)

Satisfying the harvest income by selling grain at harvest instead of doing it later, comes with a cost. The household then needs to repurchase grain later in the year in many states of nature at higher price as it is discussed in the next section. This cost is the shadow prices on the harvest income requirement goal on the farm model. This shadow price can be interpreted as the percentage loss that farmers face by selling their grain at harvest when the prices are low.

4.3.2 Minimum Food Consumption

One of the goals of the small-scale farmer' household is to assure sufficient staple food for the household. The minimum per capita annual consumption of cereals is a

function of the minimum calories and protein requirement. The minimum quantity of calories is defined as being 2,100 calories/day/adult and 50 grams/day of protein (FAO, 2003). The average farm household size is 5 adults plus children. The goals of feeding the family can be achieved through farmer's own production or local purchases or a combination²⁰.

The minimum food consumption can be satisfied through own production or through the market or a combination of both. The degree of satisfaction of the food consumption needs is a function of the state of nature. Except in the very bad states of nature, the household expects to satisfy its food consumption requirement through own-production and purchases in the market. In very bad states of nature the farmer does not expect to be able to attain these goals. Then he or she depends upon food aid or remittances from family members. Since he does not force his activities to be able to respond to these conditions, the very bad state of nature does not even enter into the planning horizon.

The household purchases food in the markets when on-farm production is not sufficient to satisfy the household food requirements for the entire year. In bad and very bad states of nature own production supply food for less than 6 months. On average and for normal years, households in the study area were able to meet the household food consumption requirements with own maize production for ten (10) months following harvest. When maize and sorghum stocks are depleted before the new harvest food needs to be bought from the market.

²⁰ In extremely bad states of nature households are not be able to meet the goal of feeding members during the whole year. Food aid is expected in such very bad states of nature.

4.3.3 Liquidity

The capital or liquidity constraint can be an important factor in the adoption of new technologies (Feder, 1982). Liquidity may constrain farmers' ability to purchase inputs. The liquidity constraint implies that the maximum amount spent by farmers in inputs for agricultural production has to be no more than his or her cash in hand, the sum of assets and current income.

Low cost credit programs with some development agencies and non-governmental agencies such as SG2000 and PAN have been used to promote technology adoption goals. Only 5% of those interviewed reported as having been part of such informal credit program.

The improved cultivar-fertilizer based technologies being promoted require additional cash for inputs (seeds and fertilizer). Because of lack of saving-credit schemes, farmers are expected to meet the increased demand for liquidity through the sale of their labor, crops, animals or earnings from the previous years. Currently, the contribution of agricultural labor wage on the total income is low (< 3%) as most farmers have their own land and the high rate of family labor used in the farm household activities (Table 2.3).

With the introduction of new technologies farmer's liquidity requirements would be increased. Increased income from new technologies would allow savings and further intensification. The storage and inventory-credit would allow farmers to obtain higher output prices, higher incomes and increase liquidity.

The estimated available capital for investment in the farm household is MZM1,800,000 (\$75) per annum, of which 67% is used for crop production (Table 4.3). The estimated available capital is average investment per farm household and it is the

sum of investments made by the average farm household in crops, livestock and non-agricultural activities.

Table 4.3 Average Estimated Investments by Farm Household in Manica, 2002

Item	Value (MZM)	%
Crops	1,200,000 (\$50)	67
Livestock	350,000 (\$14.6)	19
Others	250,000 (10.4)	14
Total	1,800,000 (\$75)	100

Source: Survey results
1 USD =MZM23,854 (IMF, 2004)

The cash available in the short run is used to purchase seeds, fertilizer, agricultural tools, animals and other inputs for non agricultural activities. With the exception of cotton and tobacco, all other crops and livestock do not benefit from the input-tied credit.

4.4 The Empirical Model

The empirical farm household model capturing the household objectives as described in the previous sections is presented. The model maximizes expected post harvest net profits subject to achieving harvest income goal, minimum food requirement subject to liquidity and other household resources (land and labor) availability. The model is state-contingent. Five states of nature are considered ranging from very bad to very good).The algebraic form of the model is as follows:

$$MaxEW = \sum_{s=1}^S \rho_s w_s \quad (4.1)$$

Subject to:

$$\sum_n \sum_s a_{cn} (C_{cs} + B_{cs}) \geq d_n \quad (2 \leq s \leq 5) \quad (4.2)$$

$$\sum_i \sum_s P_{1is} q_{1is} \geq \bar{I} \quad (4.3)$$

$$C_{is} + q_{1is} + q_{2is} = Q_{is} \text{ for all } i \quad (4.4)$$

$$\sum_i a_{ijm} * x_{im} + \sum_t a_{ijm} * x_{tm} \leq b_{jm} \text{ for all } j \quad (4.5)$$

$$Q_{is} = \sum_i y_{is} x_i \text{ for all } s \quad (4.6)$$

$$w_s = \sum_i p_{2is} q_{2is} + \sum_i r_{ts} x_t - \sum_i c_i x_i - \sum_i r_{2is} q_{2is} - \lambda \sum_i p_{2is} B_{is} \quad (4.7)$$

$$\sum_s \rho_s (w_s + (\sum_i p_{1is} q_{1is}) + p_{cs} C_{is}) = \psi \quad (4.8)$$

Where:

E – Is the expectation operator

ρ_s Is the probability of the state of nature s and $\sum_{s=1}^S \rho_s = 1$

i- Crops (technology)

s – States of nature

t – Other activities

w_s - Is the income value of post harvest sales plus the net returns to other activities

q_{1is} –quantity sold at harvest (period 1) in the state of nature s (kg)

p_{1is} – price at harvest of crop i in the state of nature s in (MZM/kg)

p_{2is} and q_{2is} -Are post harvest price (MZM/kg) and quantity (kg) sold respectively for crop i in period 2 in the state of nature s

\bar{I} - is the minimum income (MZM) required at harvest

a_{cn} - nutrient (calories and protein) content for each cereal

d_n - minimum requirement of nutrient n

C_{is} - the quantity (kg) of cereal good i for own-consumption in the state of nature s

B_{is} - the quantity (kg) of crop i purchased for home consumption in the state of nature s

Q_i - the total production (kg) of crop i

x_i is the land area (ha) used for crop i

x_t is the level (units) of non-crop activities

y_i is the yield (kg/ha) of crop i

p_{cs} - the price (MZM/kg) for the crop produced and consumed by the household in the state of nature

c_i - cost per unit area (MZM/ha) of producing crop i

λ is the premium farmers pay when buying food in period 2

Ψ is the expected total income (MZM)

a_{ij} are the technical coefficients (amount of resource j for crop i)

a_{tj} - are the technical coefficients (amount of resource j for activity t)

b_{jm} is the availability of resource j (eg. capital, labor) in period m

r_t .return for non-agricultural activities t

r_{2i} - the storage cost (MZM/kg/month) for crop i

Equation (4.1) represents the objective function which maximizes expected income over all states of nature and it is a function of post harvest income after food purchases are

deducted (equation 4.7) and the probability of each state of nature. Household nutrient requirement (equation 4.2) is obtained from own food production and food that the household buys from the market. The minimum caloric requirement was fixed at 2100 cal/day/person in all states of nature and the protein requirement is assumed to be 50 g/day/person (<http://www.fao.org/docrep/U5900t/u5900t03.htm>). Equation 4.3 represents the harvest income goal. Equation (4.4) is an identity stating that the amount produced should be equal to the amount of own-consumption plus the total amount of output sold at the two different periods. The resources used in the production process are constrained by their availability. This is captured in equation (4.5). Equation 4.6 indicates the production function. The amount produced is a multiplicative function of yield and the optimal area allocated. Equation 4.7 defines the post harvest income maximization. Equation 4.8 recovers the total household income (the value of home consumption and the income used at harvest and the net post harvest income). The model activities, objective function, constraints and identity in the model are discussed in the next sections.

4.4.1 Inventory Credit

Introduction of storage and inventory credit will allow farmers to sell their output at higher prices when the prices have recovered following the harvest price collapse. This price collapse presently is moderated by the merchants (formal and informal) who flock at harvesting time to this maize surplus producing area to buy and store and sell later. The impacts of marketing strategies on new technology adoption will be evaluated through model simulations. Sales at recovery prices (6-7 months after harvest) are considered

with grain being used as collateral for credit. Table 4.4 below, gives the expected crop (November and December) prices, 6-7 months after harvest.

Table 4.4 Expected Prices (6-7 Months After Harvest), (MZM/kg) of Major Food Crops in Chimoio

	Very Bad	Bad	Normal	Good	Very Good
Maize	3,500	2,600	1,800	1,500	1,250
Sorghum	1,750	1,500	1,400	1,250	1000
Beans	9,000	8,900	8,650	8,500	8,000
Cowpeas	3,500	3,250	3,000	2,750	2,500

Source: Computed from SIMA (2003), (November and December averages) prices.

1 USD =MZM23,854 (IMF, 2004)

The price increase from the time of harvest until the hungry season is not uniform across states of nature. During the hungry period prices in the good and very good states of nature, show only a small increase as the abundant supply of maize into the market is able to meet the demand that occurs later in the year. Figure 4.1 below indicates clearly that there is a significant price variation between June (at harvest) and December (hungry period). The year 1999, is mapped as a very good state of nature (bumper maize crop). The differences in prices in that situation are smaller than in a normal season (2001).

These price differences between harvest time and the hungry period currently represent a constraint but if adequate marketing strategies could be introduced this could change to an opportunity to improve farmers' income. The maize budget indicates that the recommended new technology is not profitable at post harvest prices but becomes profitable with prices six months later. In the farm model, the seasonal price variation is modeled assuming that the farmers are able to store and sell when the prices are higher.

4.4.2 Market Expansion

Significant between year price variations are captured in Figure 4.1 below. A very good local harvest in the 1999 and 2000 marketing seasons resulted in lower maize price. In contrast the bad cropping season in 2000/01 results in high prices in the 2001 marketing season. Between year prices collapses can be moderated by developing new markets which will expand the demand for maize grain. Demand for maize grain will be increased through agroprocessing, development of new products and as the economy growth demand for feed will be increased.

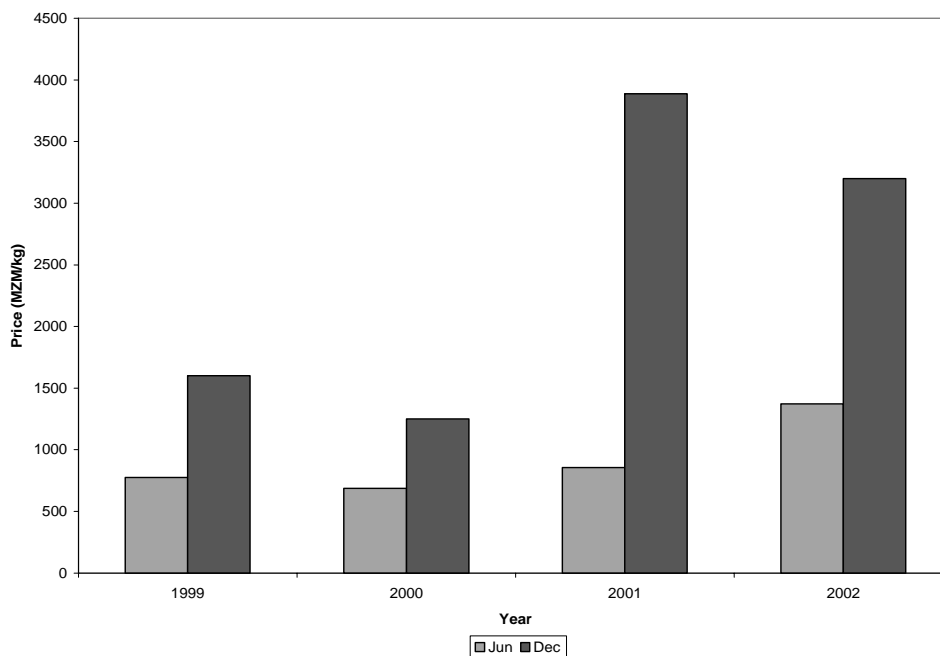


Figure: 4. 1 Maize Price Variation Between June and December in Manica (1998-2002)

Source: SIMA (various years)

Increases in demand for maize and sorghum grain will result in the moderation of the price collapse due to introduction of new technology and good and very good states

of nature. Simulation are conducted assuming that the prices in good and very good states of natures do not fall below those received in normal states of nature.

4.4.3 Public Policy in Bad Years

While in good years the prices are depressed by thin markets, in bad years the current low food price policy depresses the producer's prices. To moderate the effect of this policy in adverse rainfall years, a 30% relative price increase in maize and sorghum grains are assumed in very bad and bad states of nature. This is possible if government and non government program can administer food aid in such a way that prices are less depressed.

4.4.4 Crop Activities

The farm survey (Feb-Apr, 2003) indicated that traditional and new crop packages, especially for maize are being used. The dominant crops in the agricultural maize-sorghum farming system in Manica are maize, sorghum, beans and cotton. Other crops such as millet, sesame and sunflower are grown in small areas. These crops are not included in our representative farm model because they do not produce enough quantities to factor significantly into a representative farm model. The crop mix consists of sole crops. Intercropping, although present is not a major feature of the farming system in the study area. All the work is undertaken by the household members. The yields vary with the state of nature. Five states of nature are considered: very bad; bad; normal; good and very good (Appendix A).

Planting of both traditional and improved maize cultivars, sorghum and cotton starts in November until December depending on when rains start. Beans are planted in March in most cases, as relay crop after maize has been harvested. It is estimated that 30 kg of maize seed, 10 kg of sorghum, 15 kg of cowpea and 30 kg of cotton seed are used for planting per hectare (Normas Técnicas, 1977).

4.4.5 Other Activities

Other household activities include livestock and participation in non agricultural activities. These are included here as they contribute to the total household income but they are exogenous to the modeling exercise discussed in this thesis.

Livestock especially chicken, small ruminants and cattle are part of farmers' coping strategy. The livestock activities have two sub-activities: the cattle activity which consists of one cow and the small ruminant activity which consists of one goat. Interviewed farmers reported sales of chicken, goats and even cattle in case of emergency or to buy food in hungry periods. Livestock returns also vary with the state of nature. Drought negatively affects the return due to lack of water, pasture hence higher mortality plus price collapse.

A restocking program is underway and the offspring is (a calf in every 3 years) is given to the next beneficiary. The goats are assumed to produce off-spring every year. The expected returns to livestock activities are estimated to be MZM 1,250,000 (US\$47) for cattle activity and MZM 712,250 (US\$31) for small ruminant activity (Uaiene, 2003).

The survey identified investment in commodity trading (retail of goods such as sugar; salt; oil; cigarettes and used clothes), home based activities such as brewing

traditional beer from sorghum, manufacture of baskets and mattresses as the most important non-agricultural activities. Farm labor markets are still of negligible importance in all three districts but are growing with new commercial farm investments mainly growing cash crops, such as tobacco, cotton, sunflowers and cut flowers. The non-agricultural activity represented in the model is an investment in small retailing of manufactured goods (beer, sugar, salt, tobacco and used clothes).

The estimated non-agricultural annual income is MZM1, 500,000 (\$62.5) or 19% of total income. It should be noted that accurate figures of income especially from non agricultural activities are difficult to estimate because many farmers do not declare them to researchers. ITDG for example estimate that in Manica district, gold panning may account for more than 17 % of an average household income and it was not reported by farm households interviewed. Non-agricultural activities are unaffected by the rainfall and its distribution, thus the return to those activities are constant across the states of nature.

4.4.6 Labor and Land Constraints

This farm household model takes into account the agricultural calendar which starts with the rainy season in October/November. Agricultural chores are mainly performed by household members. The average household in the three districts of Manica has 5 adults. Men and women contribute equally to labor needs. One person-day equivalent (PDE) is equal to 8 hours of work by an adult with no distinction made between men and women. Labor requirement, expressed in person-day-equivalent, is a function of the crop growing season as indicated in Table 4.5.

Labor is most constraining at land preparation and weeding. For cotton labor shortages are observed at harvest time. Both activities are manual and performed with rudimentary instruments. The survey indicates that hired labor is not common, however, when labor is hired, a wage rate of MZM30,000/PDE (\$1.25/PDE) is expected to be paid. No hired labor is expected from the average farmers, thus all activities are expected to be performed using family labor. Labor requirements for crop operations are provided by Normas Técnicas Agrárias (MA, 1982).

Farm households own the land. Although some households own plots on the lowland, where crops can be irrigated, this model only considers the rainfed land where most of the crops are grown. The survey estimated an average endowment of 5.4 ha of arable land per household.

Table 4.5 Labor Requirement (PDE/ha) for Crop Activities

Month\crop	Maize	sorghum	cowpeas	beans	cotton
October	2	2			2
November	1	1			3
December	4	4	1	1	4
January	4	4	3	3	4
February	0	0	3	3	2
March	0	0	0	2	0
April	0	0	1.5	1.5	5
May	2	2	3	3	5

Source: Normas Técnicas Agrárias (MA, 1977)

4.5 Conclusion

This chapter set up a formal decision making framework using data from field interviews and previous studies. The household model developed here, maximizes income taking out food purchases after satisfaction of the household food subsistence objective and the harvest income objective, subject to resource constraints and production accounting in all types of production outcomes except for the very bad state of nature.

The two lexicographic goals (own food consumption and the harvest income) are satisfied in the model by crop production and food purchase. The model considers crop, livestock and non-agricultural activities all competing for resources (labor, land and capital). The next chapter will test the relevance of this decision making model as compared to several others.

CHAPTER V

MODEL VALIDATION

5.1 Introduction

The objective of the model developed in Chapter IV is to represent the average farmer decision making mechanism in terms of farming choices and allocation of resources. The model once validated is used to evaluate the impact of policy changes, particularly the introduction of new technology and of new agricultural marketing strategies.

Four variants of the model are tested in order to determine which is best able to predict the observed cropping system in Manica, the target area of our study and a prime maize and minor sorghum producer in Mozambique. The variants representing different farmers' decision making mechanisms include: a) profit maximization; b) a minimum food requirement constraint and then income maximization; c) harvest income goal and then income maximization and d) both food and harvest income constraints and then income maximization.

5.2 Model Validation

To validate the model, observed practices are compared to the four variant model runs. Data used for the model are from the survey conducted by the National Institute of

Statistics (INE, 2001). The average farm household has 5 adult equivalents and has crop, livestock and non-agricultural activities. The average farm household has a land holding of 5.5 ha of crop area.

The purpose of model validation is to determine if the model used in the simulation fits the farmer's decision making process in this region. The farm household model conceptualized in the previous chapter, has two goals: the satisfaction of household minimum food requirement and a harvest income objective. After satisfying these two constraints income maximization is undertaken.

The minimum nutritional requirement is 2100 calories/adult equivalent/day and 50grams of protein/adult equivalent/day (<http://www.fao.org>). The harvest income requirement was set to be MZM2,146,000 (\$89) based upon farmers interviews (Appendix D)²¹. This value represents the average cash expenditure of three districts surveyed in a normal year (Table 2.6) and it is likely to vary with states of nature.

5.2.1 Crop Activity Choices

As indicated in the first column of Table 5.1, the average farmer cultivates 3.0 ha of traditional maize and 0.5 ha of improved, 0.5 ha of sorghum, 0.2 ha of beans and 0.3 of cowpeas and 1.0 ha of cotton (INE, 2001).

Maize, sorghum, beans, cowpeas, and cotton as well as livestock and nonagricultural activities are all part of the model's variants results (Table 5.1). Due to pest problems farmers are known to place a limit on the land allocated to beans and

²¹ Farmers were asked to provide estimates of their annual expenses in different period of the year.

cowpeas. Our modeling exercise placed an upper limit of 0.5 ha for both beans and cowpeas.

In spite of the existence of new maize technologies in the region, none of the four model results includes new maize technologies in the optimal solution. Even when the farmer's objective is profit maximization without the two constraints, the new maize-fertilizer based technologies available to farmers in the region, do not enter the optimal solution when harvest prices were used.

Table 5.1 Base Model Results (ha) of the Average Farmer's Optimal Crop Mix

Activity	Farmer's Observed Practices ^a	Model variant			
		A	B	C	D
Traditional maize no fertilizer	3.0	2.6	2.6	3.2	3.2
Improved maize+NPK ^b	0.50	0	0	0	0
Traditional sorghum	0.50	0	0	0.50	0.50
Beans	0.20	0.20	0.20	0.40	0.40
Cowpeas	0.30	0.50	0.50	0.50	0.50
Cotton	1.0	2.2	2.2	0.90	0.90
Expected Income	\$335	\$496	\$465	\$397	\$357
Shadow price for capital (%)		45	45	45	45

Source: survey data and model results

Note A: Income Maximization; B: Income maximization plus Harvest Income Goal; C: Income maximization plus Food Goal; D: Income maximization plus Food and Harvest Income Goals

^a. INE (2001) Censo Agropecuário 1999-2000

^b. Maize OPV and 100 kg 12-24-12/ha

However, this is not surprising because in the region farmers only use improved maize when there were subsidies of various kinds and our model did not include these subsidies.

The income maximization with and without the harvest income constraint overstates the area in cotton and does not include the farmer's use of sorghum. The inclusion of a food constraint remedies both defects in the model.

Field surveys (Uaiene, 2003 and Mekuria and Sibiza, 2004) indicate that there was very little use of fertilizer in the previous cropping seasons. Without the subsidies it is unlikely that farmers under the observed harvest prices would adopt the new maize technology as it is indicated by the whole farm model solution. SG2000 has been phasing out the modern input subsidies since the year 2000. The elimination of improved input subsidies without developing rural credit markets results in maize farmers using less of the new improved seeds and agrochemicals (fertilizers and herbicides).

The results of model run in all its variants, confirm the initial hypothesis that technologies will not be introduced at the present harvest prices and without subsidies. None of the improved maize with fertilizer or the non-till technologies is adopted at the current harvest prices (Table 5.1).

The two models with only the subsistence constraint and with both constraints performed equally well. The choice of the latter was based upon farmer interviews stressing the importance of the harvest income constraint and other studies indicating its importance (Abdoulaye, 2002; Vitale, 2001) as well as farmers' behavior in bad years. Even in bad and very bad harvest years, farmers sell part of food staple and have to

repurchase. This shows the importance of keeping the harvest income in the household model formulation.

5.2.3 Household Expected Income

The model indicates that with the two constraints (harvest income and food consumption requirements) the results are closest to levels to observed behavior. As shown in Table 5.2, the observed average farm income is MZM8,049,000 (\$335) which is comparable to the model with both lexicographic goals with expected income of MZM8,568,800 (\$357). These values are comparable to recent household income estimation by the Intermediate Technology Development Group (ITDG). ITDG (2003), estimates that the average annual income in Manica district was \$350 in 2003. Farm household interviews conducted between February and April 2003 by the author indicated that the average household income of the three districts surveyed was \$335 (Table 2.3). In 1996, MAP/MSU MSE survey estimated that the share of the Manica agricultural products mean income was \$135 per household.

Table 5.2 Expected Annual Income (MZM) in Manica Province

ITDG	Survey	Lexicographic Model
MZM6,000,000 ²²	MZM8,049,000	MZM8,568,800
(\$250)	(\$335)	(\$357)

Source: ITDG (2003), survey by the author and model run results

²² The ITDG survey was conducted in 2002 and a total of 302 respondents were interviewed in Manica Province. The main focus of the ITG survey was the intermediate means of transport in the Province of Manica and Tete. Our survey was conducted in February-April 2003 and covered 57 respondents in three districts of the Manica Province

5.2.4 Subsistence Food

When satisfying household food subsistence needs enters the model, the crop mix is adjusted (Table 5.1, column C and D) to incorporate sorghum. Without this constraint in the model the farmer would have a large share of his or her area planted to cotton, a cash crop. The farmers place a higher value on cereals as indicated by the crop mix with the inclusion of food subsistence constraint in model. The optimal crop mix as indicated by column C and D on Table 5.1 is closer to observed farmer's choices than without the food self-sufficiency goal.

The subsistence food target is achieved through on farm production and market purchases, except in very bad state of nature. The very bad state of nature, which occurs 5% of the time, was not included in the household decision making because when it does occur the outcome of the cropping season is an exceptionally low harvest. When very bad state occurs, help from family members, food aid, in the form of public free distribution or food for work is expected.

5.2.5 Harvest Income

The average farm household in the three districts, spent MZM2,146,000 (\$89) at harvest time on several expenses as indicated in Table 2.6. This represents about 27% of their annual income of about \$335 in a normal year. The amount spent at harvest was used as a proxy of the target household harvest income for the average farm household. Most of the target income is satisfied by selling crops. To satisfy the harvest income requirement the model solution indicates sales of maize, beans and cotton at harvest time.

The harvest time sales indicate how valuable the harvest income objective is for the farm household in Manica.

Eliminating the harvest income goal and selling the grain 6-8 months later when prices recover, allows an increase in income. This indicates that policy actions that allow reduction or elimination of harvest sales could lead to a substantial increase in farmers' expected income. Thus far, only the traders have exploited the price swings between the time of harvest and the lean period. This is discussed in the next chapter when marketing strategies are introduced.

Contribution to harvest income comes from sales not only of maize but also of other crops mainly beans and cotton. In very good states of nature more maize grain is sold than in the bad states of nature. Figure 5.1, indicates that the amount of maize sold varies from as low as 1000 kg in bad states of nature to as high as 2000 kg in very good states of nature. Cotton with its pan-territorial and pan-temporal price contributes also to harvest time expenses and it is used by farmers to minimize the amount of maize grain sold at harvest.

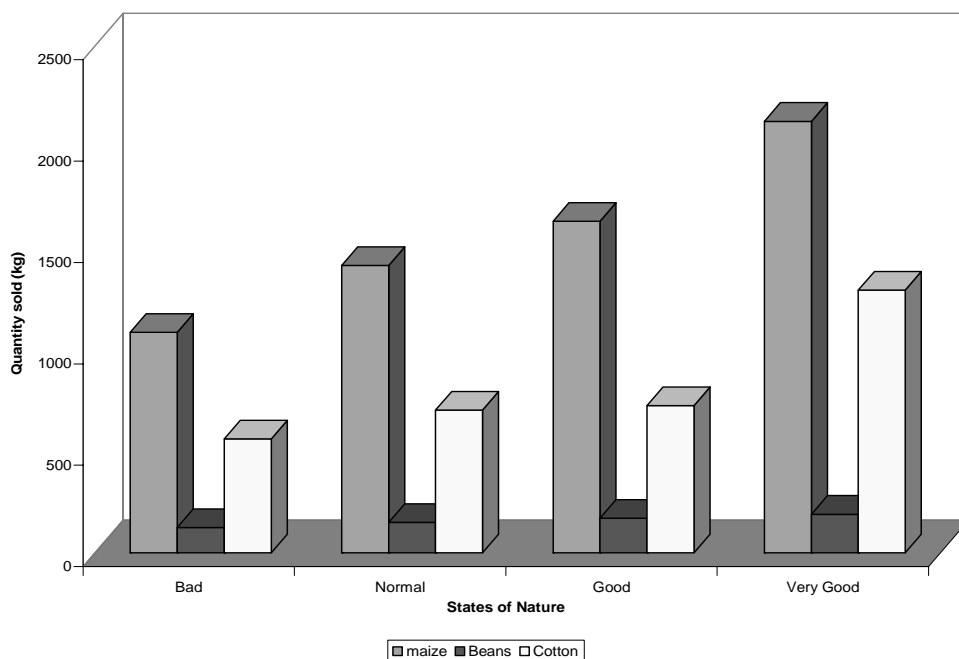


Figure 5.1 Quantity of Grain Sold at Harvest by State of Nature, Manica (2002)
Source: Model Results

The pressure to sell some of the household's maize grain to meet harvest income needs represents an income loss to the household as prices increase when maize is stored for 6 months. The price increase varies from 65% in good years to 150% in bad years (SIMA, 2003).

5.2.5 Liquidity

Liquidity constraints the amount of inputs that farmer can buy. The average cash available to farmers after a normal year in the farm household survey was MZM3,600,000 (\$150). At this level of liquidity, the opportunity cost of cash, as given by the model, is 45%. This means that for each additional unit of liquidity becoming available

there is a marginal rate of return of 45%. This shadow price of capital is large enough to create incentives for farmers to continuing investing.

The lower the liquidity level, the higher the expected returns to liquidity and the higher the proportion of land allocated to activities requiring less cash expenditures such as traditional maize.

5.2.6 Labor

Labor is only binding during harvest time (January) with opportunity cost valued at MZM42, 000/PDE (\$1.75). This shadow price for labor is higher than the MZM30, 000/PDE (\$1.25) which is the reported market value of a person day equivalent (PDE) used in the model. Labor has a high value in January because of crop calendar activities that require a considerable amount of labor (weeding of cotton and beans). This is consistent with the labor shortage pattern in the study area.

5.3 Conclusion

Evidence of farm income from the four lexicographic farm model's results is consistent with the observed practices in Manica. There is no apparent difference in the farm activities with the two goals (harvest income and minimum food requirement) together and the food subsistence goal alone, but the former is more consistent with farmers' observations and behavior.

The farm model results indicate an explanation for the slow and erratic adoption and diffusion of new maize technologies during the last decade. These results confirm our earlier hypothesis that without new marketing strategies or continuing subsidies, adoption

of new maize technologies will not occur. This results apparently from the current low output prices received by farmers.

The next chapter aims at analyzing the question of whether farmers would or would not adopt new technologies if new marketing systems/strategies are created to increase the probability of these new activities.

CHAPTER VI

INTRODUCING NEW MARKETING STRATEGIES

6.1 Introduction

In the previous chapter none of the new maize cultivar-fertilizer based technologies are adopted. New technologies are not expected to be adopted unless farmers can make a profit from their use. This chapter analyzes the potential effects of marketing strategies on technology adoption and farmers' income.

Three scenarios are simulated: storage and inventory credit which allow farmers to sell after prices recover; moderation of price collapse in good and very good years and an improvement of price in bad years.

The first scenario assumes that some institution is willing to provide inventory credit. Then farmers can borrow against their stock of grain to cover their expenditure requirements during the storage period. The grain stock is sold at least 6 months later allowing farmers to repay their loans and profit from the increased price.

The second scenario assumes expansion of maize markets. There is a growing demand for animal products, especially poultry in Mozambique. Development of new domestic maize markets for processed food and feed can help expand domestic markets and consequently moderate the price collapse between years resulting from the abundant grain of good and very good years.

The third scenario in our simulations is the reversal of the low food price public policy. Food aid programs run by government, development projects and NGOs by bringing in maize grain or substitutes such as rice, often drive the price of maize down from the increase in adverse weather years. In the simulation, we assume that this price depressing effect would be reduced.

Table 6.1 below, shows the effect of different marketing strategies on the price of maize. The inventory credit is expected to increase the producer price in all years. Both moderation of price variability in good years and the reduction of government intervention in bad years are considered in combination with inventory credit.

Table 6.1 Maize Prices (MZM/kg) for Different States of Nature and Policy Intervention Scenarios

Intervention	State of nature					Exp. price
	V. Bad	Bad	Normal	Good	V. Good	
Without new policy ^a	2100	1680	1260	1000	960	1293
Inventory Credit	3500	2600	1800	1500	1250	1928
Price collapse moderation	3500	2600	1800	1800	1800	2045
Less Gov intervention	4900	3640	1800	1500	1250	2206

1\$US= MZM 23,854 (IMF, 2004)

^a. Source: SIMA (various years). The prices of the other scenarios are estimated.

The expected price for each intervention is MZM1293/kg (\$0.05/kg) for the current situation, MZM1928/kg (\$0.08/kg) for inventory credit intervention, MZM2045/kg (\$0.09) for the inventory credit and good year moderation of price collapse and MZM2206/kg (\$0.09) for the inventory credit and low government intervention in

bad years. The interventions result in 49%, 58% and 71% expected producer price increase respectively for inventory credit, the combination of inventory credit and price moderation in good years and inventory credit and reduced government intervention in bad years.

The price scenarios assume that in good and very good years prices reach normal rainfall year price level while in bad and very bad years, if there were no depressing effects of public price stabilization policies, the price level can be 40% higher.

6.2 Potential Impacts of Storage and Inventory Credit

Assuming that farmer's grain can be used to secure loans to cover the harvest income requirements, the model results suggest that storing and selling later in the season increase potential expected income by 58% as compared to the current system where most of the grain is sold just after harvesting (Table 6.2). The expected income increase obtained from storage is greater than the interest rates of 36% per annum which farmers are expected to pay for borrowed capital (IMF,2004), thus, it would be profitable for farmers to store maize grain and sell when prices raise for both traditional and improved packages. The increase in income is a combined result of the introduction of new maize technology, which increases total production and the ability to sell at higher farm gate prices.

With inventory credit which results in better output/input price ratios, one of the improved package (improved maize and a basal fertilization with a compound of NPK) is adopted. Table 6.2 indicates that 1.5 ha is allocated to the new maize cultivar and fertilizer resulting in small reductions of land allocated to the other activities namely

sorghum, cowpeas, beans and cotton. Improved maize replaces cotton as cash crop. With the introduction of inventory credit, the area under cotton decreases by 33%. Another significant change is the area allocated to the traditional maize which is reduced by 22% in favor of the improved package. Thus, inventory credit by allowing sales at a later stage after harvest makes it profitable to adopt the improved maize package.

The maize technology adopted is a package consisting of new improved open pollinated variety and a 100 kg/ha of compound fertilizer NPK 12-24-12 applied before planting. The results show that improvement of the fertilizer/grain price ratios provides enough incentives to farmers for adoption of improved cultivars as well as fertilizer. This is an important result as soil fertility ranks high in the biophysical constraints to crop yield increase for maize production in Manica. This also confirms our earlier hypothesis that new marketing strategies would encourage a more rapid introduction of new agricultural technologies.

Table 6.2 Land Allocation (ha) and Income under Current and Inventory Credit Systems

Activity	Base Model	With Inventory Credit
Traditional maize	3.2	2.5
Improved Maize+NPK	0	1.5
Trad sorghum	0.5	0
Beans	0.4	0.4
Cowpeas	0.5	0.5
Cotton	0.9	0.6
Expected income (MZM)	\$357	\$565
Income increase (%)	-	58%
Opportunity cost of capital	45%	82%

These simulation results suggest that farmers would adopt new maize technologies under an inventory credit scheme. With adequate storage and post-harvest financing farmers could benefit from prices swings if marketing strategies could be adopted. The high shadow price for capital, 82%, indicates potential for continued investments in the new technologies and marketing strategies as farmers accumulate and re-invest profit over time. Higher output prices will lead to increased incomes and thus to a dynamic effect of further agricultural intensification between years as farmers will have increased liquidity to pay for the modern inputs.

Storage seems to be a viable option given the large price variability. If an inventory credit scheme could be established, according to the simulation model farmers could gain a significant amount of extra income as they can sell later, without the pressing need of urgent cash to repay debt or to finance consumption.

Household income in each state of nature is calculated, except in the very bad one when food aid is expected and harvest income requirement are unlikely to be met. This state of nature is excluded from the model optimization. The probability of each one of the four remaining state of nature, after excluding the very bad state of nature, is recomputed and it is presented in Table below. Household income in each state of nature with and without inventory credit is given in Table 6.3. The sum of the probability of the new sub-set of states of nature sums to 1. Incomes vary from \$170 in bad years to \$696 in very good years, without inventory and from \$350 to \$987 in bad and very good years respectively. The highest increase in income (106%) is observed in the bad state of nature. This means that the higher prices offered in the bad state of nature offset the lower output.

Table 6.3 Household Incomes (\$) With and Without Inventory Credit in Different States of Nature

State of nature	Probability	Without inventory	With inventory	% Increase
Bad	0.21	\$170	\$350	106
Normal	0.42	\$307	\$539	75
Good	0.32	\$493	\$675	37
Very Good	0.05	\$696	\$987	42
Expected values		\$357	\$565	67

Source: Model results
1 USD =MZM23,854 (IMF, 2004)

The expected household income as indicated earlier and reported again in Table 6.3 are \$357 for the current scenario without inventory credit and \$565 with storage and inventory credit. This represents a 58% increase in expected income.

Currently there is no active inventory credit in Manica but farmers seem to be willing to improve the marketing linkages by working together in associations as we observed in all the three districts surveyed. Under the auspices of Manica Small Farmers Union (UCAMA), TECHNOSERVE, ACDI/VOCA and several others governmental and non-governmental organizations, small farmers are organizing themselves in groups or associations to receive marketing assistance in the form of agribusiness management and market information and contacts.

Some associations in Manica district have been bulking up their maize grains and selling them to traders. This is an indication that it would be possible for members of the

associations to agree to the concept of storage in order to obtain inventory credit and take advantage of the price increase.

6.3 Moderating the Price Collapse due to Good Harvest

The results of model run with a moderation of prices in good and very good states of nature and in the presence of inventory credit do not result in further introduction of new technology, but there is a 4.5% increase in income when prices in good and very good states of nature are assumed to stay on their normal year levels, rather than collapsing.

6.4 Moderating Price Collapse in Bad States of Nature

The maize price increase in bad cropping year erodes consumer purchasing power, particularly for poorer consumers in urban areas. The government preoccupation to protect those urban consumers and those poor farmers who are net buyers in bad years, make it appeal for international food aid.

Food aid is usually in form of maize grain or substitute commodities such as rice. While maintaining low food prices for net buyers, this public intervention drive the producer price down. Data from SIMA (2003) indicated that the price of maize in Manica has fallen by more than 50% with arrival of food aid.

A model simulation was conducted assuming a 50% increase in the normal prices of bad years combined with inventory credit. There is no change of crop mix compared to the inventory credit alone but the result of moderation of public intervention in bad years and inventory credit there is a 68% increase in income compared to the without inventory credit scenario. Rural producers who are net sellers are pleased with the maize price

increase because it increases their expected income and spurs cereal production in the country.

6.5 Combining Marketing Strategies

Policy actions are likely to have synergistic effects. Combinations of different marketing strategies (moderation of price collapse in both bad and good states of nature and storage and inventory credit) are considered.

The results of different experiments are presented in Table 6.4. The first column of the Table shows the current system. The second column indicates the crop mix when only inventory credit is introduced. Column C reports the results of the combination of inventory credit and the moderation of price collapse due to market expansion.

Table 6.4 Land Allocation and Income Effect of Price Policies

Technology	Model				
	A	B	C	D	E
Trad maize	3.2	2.5	2.5	2.5	2.3
Improved Maize+NPK	0	1.5	1.5	1.5	1.8
Trad sorghum	0.5	0	0	0	0
Beans	0.4	0.4	0.4	0.4	0.4
Cowpeas	0.50	0.5	0.5	0.5	0.5
Cotton	0.9	0.6	0.6	0.6	0.5
Expected income	\$357	\$565	\$610	\$598	\$645
Income increase (%)	-	58	71	68	81
Shadow price of capital (%)		82	82	82	82

Source: Model results

A. Base Model; B. Inventory Credit; C. Inventory credit and moderation of price collapse in good and very good states of nature; D. Inventory credit and moderate public intervention in bad years and E. Combination of scenarios B+C+D

The result of the combination of inventory credit and moderation of price collapse in good harvests is an increase of 71% in expected income when compared with the current system. The combination of inventory credit and low government intervention to lower food prices, result in a 68% increase in farmer's income as indicated by column D. Combining inventory credit, moderation in price collapse in good years and no price depression in bad years, results in a substantial increase in the area allocated to the new maize package from 1.5 ha to 1.8 or a 20% increase in intensification.

With all combined marketing strategies 32% of the total land available for the average household is allocated to the improved maize package. Acreage of cotton is slightly reduced. Traditional sorghum does not enter into the crop mix. Field evidence shows that better farmers in the region, with improved systems, do not grow traditional sorghum.

Combining all three marketing strategies there is an 81% income increase above the current system (Table 6.4). With these combined strategies there is a clear intensification of maize as indicated by higher cropped area under improved maize and fertilizer. The area under the new technology is now 1.8 ha (Table 6.4) compared to no adoption when no marketing policies are adopted.

Clearly the different marketing strategies have a significant effect on adoption of the new maize technology and farmer's income as indicated by the results presented in Table 6.3 and 6.4. Furthermore, the high shadow prices (82%) with present liquidity indicate a potential dynamic effect. The combined technology and marketing innovations are highly profitable. Farmers can earn increased profits from the system and then reinvest. So the ultimate income effect will be even greater.

Table 6.5. Household Incomes (\$) for Different Marketing Strategies

State of nature	Marketing Strategy				
	A	B	C	D	E
Bad	170	350	350	508	508
Normal	307	539	539	539	539
Good	493	675	780	675	785
Very Good	696	987	1215	987	1215
Expected income	357	565	610	598	645

Source: Model results

1 USD =MZM23,854 (IMF, 2004)

Marketing strategies: A. Base Model; B. Inventory Credit; C. Inventory credit and no price collapse in good states of nature; D. Inventory credit and moderate public intervention in bad years and E. Combination of scenarios B+C+D

The expected income for each marketing strategy varies with state of nature as indicated in Table 6.5. The lowest income is obtained in bad states of nature and with no improved marketing strategy and the highest income is obtained in very good states of nature with a combination of inventory credit and market expansion.

6.6 Conclusions

The objective of this chapter was to examine the interaction of new maize technology and marketing strategies. The marketing strategies allow an improvement in the output price received by farmers and consequently an improvement in their income. New capital-intensive cultivar-fertilizer based maize technology is only adopted when maize grain prices rises through the introduction of new marketing strategies.

These results draw attention to the importance of the demand side as government and non-governmental organizations in Manica, spend most of their effort in demonstrating the potential yield advantage of the new packages without taking into account issues related to profitability of the new technologies or marketing strategies.

The increased expected farm household income due to the interaction of new marketing strategies and new technologies would allow farmers to make more investments in the new technologies as they increase their liquidity from the income effects of the combined strategy. Farmers can take advantage of seasonal price variation if the pressure to sell at harvest is moderated through storage and inventory credit. This strategy can be combined with the development of new markets for maize which will allow the moderation of price collapses in good years. Also the government and NGOs need to consider other policies for alleviating poverty than making farmers poorer through driving down prices in adverse weather years.

CHAPTER VII

CONCLUSIONS AND POLICY IMPLICATIONS

7.1 Main Findings

The premise of this work was that new marketing strategies along with improved technologies would increase farm profitability through higher output prices, thus expanding the use of new technologies. The low profitability of new maize technological packages in Manica discourages farmers from using inputs or making significant investments in new maize technologies. With maize sales at harvest crop budgeting and farm modeling indicated insufficient payoffs for the adoption of new technologies. This can be reversed if farmers can seize the opportunity to sell later thereby using to their advantage the output price seasonality. Higher maize producer's price as a result of introduction of new marketing strategies provides incentives for farmers to adopt new maize technologies and increase farmer's income.

This study found that the short season characteristic of the new sorghum cultivars is not attractive in most years. The traditional late maturing, guinea type sorghum cultivars have a better adaptation to this environment with long rains than the improved sorghum cultivars. Adverse years are expected in less than 30% of the time in the study area which means that short season cultivars are not attractive in most years. This is combined with greater mold and bird problem with Caudatum type than with Guinea type

cultivars. This means that agricultural research should re-examine the sorghum development strategy for this agro-ecological region, providing intermediate to long-season sorghum cultivars. Improvement of the existing photoperiod sensitive sorghum is an option in the process of generating new sorghum cultivars. Nevertheless, storage of the traditional sorghum cultivar and of new improved maize cultivars is highly profitable.

Farm households in Manica adopt higher input use maize if policy actions aimed at eliminating or reducing the price collapse and thus improving the output/input price ratio are adopted. The high rate of return to capital (82%) on investment in new technologies and new marketing strategies indicates a potential dynamic effect of continued internal capital generation and further investment in these new technologies and marketing strategies.

7.2 New Marketing Strategies

In response to seasonal price movements for maize, holding inventory of maize grain results in increased farm household income. The storage of maize is financially attractive for farmers as the price differential between harvest and post-harvest (6-9 months) is sufficient to cover the cost of holding the grain and opportunity cost of capital.

Marketing groups or farmers' associations can pool their grain and use it as collateral to obtain financial services. Groups or associations will benefit more than individual farmers as their bargaining power increases and reduces transactions costs. The gains from inventory credit will ultimately disappear as more farmers participate in the scheme.

This thesis found that with structural changes in the demand of maize due to development of new food products and feed and resulting demand expansion, there is a potential for more rapid diffusion of maize technology which will result in increased farm income. Maize and sorghum are the main components of poultry feed. The growing poultry industry will demand more feed and consequently more of these cereals.

A safety net program intended to protect the poor when food prices rises in bad years is being implemented in Mozambique. As food prices increase with bad weather, the government and NGOs distribute food to vulnerable groups or subsidize targeted food distribution or food for work. Although food aid is concentrated where the harvest is poor, the grain quickly spills over to unaffected areas, bringing the prices down and depressing farmer's income. Another way to help the poor other than by making farmers poor is to increase their incomes.

7.3 Policy Implications

The introduction of new maize technologies in the high potential area of Manica, central Mozambique, requires associated marketing strategies to increase the farmer's income and reduce the financial risk of using new technology. Farmers adopting new agricultural technologies are more at risk from collapsing prices than non-adopters due to increase in financial expenditures in improved seeds and fertilizers.

Agricultural knowledge systems and development agencies which promote new agricultural technologies need to incorporate in their agenda, activities that moderate the price collapse and thereby increase expected prices in order to help the process of technology adoption and diffusion and increase farmers' income.

Farmers individually or in groups or banks can finance storage. Inventory credit schemes are then appropriate means of obtaining the potential benefits brought by seasonal output price variation. Improving farmers' access to finance would facilitate technology adoption and the introduction of new marketing strategies. This marketing strategy brings closer farmers and financial institutions.

The agricultural extension package being provided in Manica has got some shortcomings. Among the setbacks, the program does not have a market component but only focuses on physical production without planning the fate of surplus produced stock. Many institutional changes will be needed to support agricultural growth in Manica. These changes should aim, among others at encouraging the creation of cooperatives and farmers' organizations.

The Government of Mozambique and development agencies should continue to encourage farmers to organize themselves into groups and associations to increase their empowerment. Farmers' groups and farmers' organizations not only improve farmers' negotiating power, as well as reducing the transaction costs²³ of accessing input and output markets. The negotiating power of farmers' group can foster the development of group lending schemes that facilitates small farmers' access to credit.

Policy makers should improve the economic environment for agricultural intensification and rural development. The availability of divisible technologies suitable to targeted agro-ecologies and the recognition by policy makers of the need and the importance of higher incomes for producers is crucial for agricultural success in

²³ It is envisaged that the start-up costs, the initial cash and investment to start a new inventory credit, which includes management costs is likely to be subsidized by Government and or NGOs. CLUSA and several NGOs have been supporting the start-up costs for the formation of marketing groups. Training in business management is core activity of these NGOs.

Mozambique. New maize technologies plus a combination of marketing strategies resulted in more than 60% increase in expected farmer's income. These results call for the concerted effort of the development, dissemination of new agricultural technologies and those in development projects to link both the supply and the demand side.

Presently the focus of INIA is on the development and supply of new agricultural technology with breeding, agronomy, entomology and plant pathology. INIA is ill equipped to undertaking research on market innovations and policy. Both research and extension systems pay little attention to the factors involved in marketing and processing of agricultural products. It is critical that the agricultural knowledge system in Mozambique focus more attention on marketing and processing, two areas critical to successful dissemination of new agricultural technologies among farmers.

Mozambique needs not only food technology/agribusiness capacity but also a social science capacity within its agricultural research and extension institutions. The new capacity will help institution such as INIA and the extension services, to conduct farm household surveys, to set research priorities, to conduct technology adoption studies and to access the socio-economic impacts of new technologies among other core activities.

Expansion of domestic demand will help increase producer prices in the face of expanding supply. Policy makers should place a greater role for the growth of food and feed processing and distribution industries. Processed maize could be used further for making other food products. The development of a domestic livestock industry especially poultry will also increase the demand of for feed. Both increased food and feed demand will contribute to moderate the price collapse due to good rainfall and or introduction of new technologies.

A critical and perhaps controversial issue is the dilemma to ensure that farmers receive higher producer prices for their output on the one hand and the government desire to keep food prices low for the net food buyers, especially through food aid imports. It is important to ensure that food aid imports are not providing disincentive to domestic production and adoption of new agricultural technologies. Public food distribution should be targeted to the needy. To protect the poor when food prices rise abnormally, public food procurement to feed the vulnerable groups or subsidizing targeted food distribution or work programs with wages paid in cash or in food or a combination of these measures should continue. However, whenever possible, it would be helpful to allow conversion of food aid to cash aid to obtain food supplies from sources other than aid giving countries.

Enabling farmers to profit from the utilization of new yield enhancing and/or cost saving agricultural technologies should be part of an integrated agricultural growth strategy for the prime agricultural area such as Manica.

The challenges faced by sorghum in Manica are greater than the ones faced by maize. The early maturing caudatums varieties of sorghum do not fit well in the agroclimatic conditions of the Manica plateau. These varieties do not perform better than the traditional guinea varieties. The local varieties should be part of the national and regional breeding program if new improved varieties are to be developed for this high rainfall area. Policy makers and research institutions should give priority to developing sorghum cultivars that have a phenology which matches the agroclimatic conditions of the target area, particularly ensuring that the grains mature as the weather become dry so that the damage by rain is minimized, while addressing the issue of soil fertility and several biological constraints such as weeds, particularly *Striga* and pests.

7.4 Limitations of the Study and Future Research

This study was based on data collected in field interviews including farm household characteristics, production, marketing, income and expenditures. Elicitation of farm incomes is a difficult task as farmers are reluctant to declare all their incomes thus underestimation of income and liquidity may be a real limitation. Data on farm household's incomes and expenditure need to be systematically collected and analyzed.

This study used a household model that maximizes expected income subject to satisfaction of farm household food requirements and harvest income as farmers' risk management strategies. Both energy and protein requirement and household income were fixed for all states of nature. It is expected that farm households will vary their food subsistence and harvest income requirement with different states of nature, unfortunately, this variation was not captured in this study. Research is needed in order to understand the adjustments made with different states of nature, in both food requirement and harvest income needs and their effects on the household decision making process.

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Appendix A: The States of Nature and Crop Yields

This appendix discusses the states of nature and crop yields used in the modeling activities contained in Chapter 5 and 6.

Crop yield and production, especially those of the maize, in Mozambique is greatly influenced by rainfall. Good rainfall (quantity and distribution) often results in good yield. The status of a cropping season in Manica is classified according to the rainfall pattern.

The different yield outcomes as a result of a combination of several factors among which is the rainfall quantity and distribution is called in this work, states of nature. The probability of occurrence of each state of nature was determined following the framework used by Vitale (2001) and Abdoulaye (2002). Annual rainfall for the region was classified as poor, normal or good based on the deviation from the historical rainfall average. A bad year is one with more than 1 standard deviation less than the mean, a normal year is within 1 standard deviation and a good year is one with annual rainfall at least one standard deviation above the mean.

Rainfall distribution more than the amount of rainfall itself determines the outcome of a cropping season. The 2002/03 for example, was a typical example of a year with bad rainfall distribution. Rainfall started as often does in November but a dry spell followed (more than 30 days without a drop) especially during maize flowering. Although the total rainfall was above average the outcome of the cropping season was bad, thus a bad state of nature.

The rainfall distribution during the cropping season is equally classified as bad, normal or good. The mean number of days in February without rain was used as proxy for rainfall distribution. A year with bad rainfall distribution is one with more than 1 standard deviation above the mean number of days without rain, an average year is one within 1 standard deviation and a good year is one with one standard deviation the below average.

Table A.1 gives the combination of rainfall quantity and rainfall distribution and associated states of nature. Five states of nature were assumed to represent all possible combinations of outcomes that farmers could encounter. The final outcome of a particular cropping season, as given by crop yield, is thus classified as very bad, bad, normal, good or very good.

Table A.1 Rainfall (Quantity and Distribution) and Associated States of Nature

Rainfall Quantity	Rainfall Distribution		
	Poor	Average	Good
Poor	Very Bad	Bad	Bad
Average	Very Bad	Normal	Good
Good	Bad	Good	Very Good

Source: Author based on INAM (various years) historical rainfall data

Based on these criteria and the historical data on yields and rainfall, the associated probabilities of each state of nature were determined as: very bad (0.05); bad (0.20); Normal (0.40); Good (0.20) and Very Good (0.05).

Table A.2 Expected Yields (kg/ha) of Activities per State of Nature

Activities	States of Nature				
	Very Bad	Bad	Normal	Good	Very Good
Trad Maize	250	500	700	850	1100
Maize 1	500	750	950	1200	1500
Maize 2	500	750	1200	2000	3750
Maize 3	600	850	1500	2500	4100
Maize 4	500	750	1750	2500	4200
Trad Sorghum	250	300	400	560	750
Beans	150	250	400	650	850
Cowpeas	50	100	350	600	750
Cotton	250	300	500	750	1200

Source: INIA (1998), SPER-Manica (2002) and author's calculations.

Farmers were aware of different rainfall outcomes and did predict the amount of grain in five different states of nature namely very bad, bad, normal, good and very good. Rainfall distribution plays a major role in determining the states of nature. A dry spell during flowering or cob or head formation, regardless of amount of rain gives a bad

outcome in terms of cereal yield. Crop yield were calculated from on-farm trials conducted by INIA and Sper-Manica.

Appendix B: Maize and Sorghum Budgets

Both crops budgets were calculated using on-farm data from INIA-SPER-SG2000 and PAN in Manica. Data are from the districts of Gondola, Manica and Sussundenga. Yields of both cereals are discounted for losses from pests at 1% a month starting at harvest. Budgets are estimated using average prices for maize from SIMA and sorghum from SIMAP-Manica. The budgets uses June and December prices, ie, just after harvest and few months later when the prices are high. Labor requirements used in the partial budget were those used by Howard et al. (2000). Average daily wage is estimated at MZM30,000/PDE. The minimum wage in Mozambique is set to MZM800,000/month. The cash cost of labor is not included in the financial analysis because most of the operations are done mainly using household labor.

The budget is calculated as follows: Revenue: The revenue is the product of crop yield in each state of nature and the price. Revenue in June and December is considered for each state of nature. Cost includes, the package cost, the interest paid on the inputs received. Net income is the difference between gross revenue and total cost. The net income is a return to capital and management.

Agronomic data used for crop partial budgeting is from INIA (Sussundenga) and SPER in Manica. On-farm trials were conducted and yields recorded. Higher yielding

varieties of maize and sorghum combined with fertilizer more than double expected yields when compared to the traditional maize and sorghum farming systems. The expected yield for traditional maize is 675 k/ha while the improved cultivar and fertilizer is 1755 kg/ha. The expected sorghum yields are respectively 440 kg/ha for the traditional cultivars and 900 kg/ha for the improved ones.

The improved maize package includes purchases of 30 kg of seeds per hectare at MZM20,000/kg (\$0.83/kg), the use of 100 kg/ha of compound fertilizer at MZM10,000 (\$0.42/kg) and 100 kg/ha of Urea at MZM8,000/kg (\$0.33/kg). The producer's price varies with the state of nature. Sorghum package includes 10 kg of seed per hectare, 100 kg of compound 12-24-12 and 50 kg/ha of Urea (46% N).

Table B1. Budget of Improved Maize and Fertilizer Technology

State of Nature	Bad	Normal	Good	Very Good
Yield (kg/ha) June	850	1500	2500	4100
Yield (kg/ha) Dec	824	1382	2425	3977
June producer's price (\$/kg)	0.04	0.04	0.03	0.03
Dec producer's price	0.08	0.08	0.06	0.05
Jun Revenue (\$/ha)	32.07	54.08	83.84	123.75
Dec Revenue (\$/ha)	69.13	104.31	142.32	208.40
Total package cost	100.61	100.61	100.61	100.61
Seed cost (\$/ha)	25.15	25.15	25.15	25.15
Seed quantity (kg/ha)	30	30	30	30
Seed price (\$/kg)	0.84	0.84	0.84	0.84
Fertilizer cost (\$/ha)	75.46	75.46	75.46	75.46
12-12-12 (\$)	41.92	41.92	41.92	41.92
Urea (\$)	33.54	33.54	33.54	33.54
June interest rate(3% per month)	27.17	27.17	27.17	27.17
Dec Interest (\$)	30.18	30.18	30.18	30.18
Storage cost (\$)	13.68	24.15	40.24	65.98
Family labor (days/ha)	56	66	73	73
Tools and bags (\$/ha)	1.23	1.23	1.29	1.59
Hand tools (\$/ha)	0.87	0.87	0.80	0.77
Bags (\$/ha)	0.37	0.37	0.49	0.82
June Net income(\$/ha)	-96.94	-49.12	-45.22	0.00
Dec Net income(\$/ha)	24.03	84.04	70.61	110.64
June Net income(\$/labor day)	-2.36	-0.99	-0.62	-0.08
Dec Net income(\$/labor day)	0.43	1.27	0.97	1.52

Source: Author's calculations

Note: Storage cost at MZM48/kg/month

1 USD =MZM23,854 (IMF, 2004)

Yield in December is 95% of the June yield due to pest losses and physical damages.
12-24-12, 100 kg/ha (MZM10,000/kg); Urea 100 kg/ha (MZM8,000/kg)

Table B2. Budget of Traditional Maize Technology

State of Nature	Bad	Normal	Good	Very Good
Yield (kg/ha) June	350	700	850	1100
Yield (kg/ha) Dec	340	631	825	1067
June producer's price (\$/kg)	0.04	0.04	0.03	0.03
Dec producer's price	0.08	0.08	0.06	0.05
Jun Revenue (\$/ha)	13.21	21.92	33.20	123.75
Dec Revenue (\$/ha)	28.46	38.94	48.39	55.91
Total package cost (\$)	100.61	100.61	100.61	100.61
Seed cost (\$/ha)	25.15	25.15	25.15	25.15
Seed quantity (kg/ha)	0.00	0.00	0.00	0.00
Seed price (\$/kg)	0.84	0.84	0.84	0.84
Storage cost (\$)	5.63	11.27	13.68	17.71
Family labor (days/ha)	75	75	80	78
Tools and bags (\$/ha)	1.96	1.96	2.01	3.78
Hand tools (\$/ha)	1.47	1.37	1.22	2.20
Bags (\$/ha)	0.49	0.78	0.79	1.58
June Net income (\$/ha)	-13.90	-2.87	1.34	4.27
Dec Net income (\$/ha)	20.87	25.52	32.70	34.43
June Net income \$/labor day	-0.19	-0.04	0.02	0.05
Dec Net income \$/labor day	0.28	0.34	0.41	0.44

Source: Author's calculations

Storage cost: MZM48/kg/month

1 USD =MZM23,854 (IMF, 2004)

Note: Yield in December is 95% of the June yield due to pest losses and physical damages.

Table B3. Budget of Improved Sorghum and Fertilizer Technology

State of Nature	Bad	Normal	Good	Very Good
Yield (kg/ha) June	650	800	1000	1500
Yield (kg/ha)	630	776	970	1455
June producer's price (\$/kg)	0.05	0.04	0.04	0.04
Dec producer's price	0.06	0.06	0.05	0.04
Jun Revenue (\$/ha)	32.70	33.54	37.73	53.45
Dec Revenue (\$/ha)	39.65	45.54	50.83	61.00
Total package cost	67.07	67.07	67.07	67.07
Seed cost (\$/ha)	8.38	8.38	8.38	8.38
Seed quantity (kg/ha)	0.00	0.00	0.00	0.00
Seed price (\$/kg)	0.84	0.84	0.84	0.84
Fertilizer cost (\$/ha)	58.69	58.69	58.69	58.69
100 kg/ha of 12-12-12 (\$)	41.92	41.92	41.92	41.92
50 kg/ha Urea (\$)	16.77	16.77	16.77	16.77
June interest rate(3% per month)	7.28	7.28	7.28	7.28
Dec Interest rate (\$)	7.89	7.89	7.89	7.89
Storage costs (\$)	10.46	12.88	16.10	24.15
Tools and bags (\$/ha)	1.23	1.23	1.29	1.59
Hand tools (\$/ha)	0.87	0.87	0.80	0.77
Bags (\$/ha)	0.37	0.37	0.49	0.82
June Net income(\$/ha)	-91.46	-44.56	-38.51	-26.44
Dec Net income(\$/ha)	13.41	22.33	24.96	23.43
June Net income(\$/labor day)	-1.21	-0.52	-0.39	0.09
Dec Net income(\$/labor day)	0.58	0.34	0.56	0.71

Source: Author's calculations

1 USD =MZM23,854 (IMF, 2004)

Note: Yield in December is 95% of the June yield due to pest losses and physical damages.

Table B4. Budget of Traditional Sorghum Technology

State of Nature	Bad	Normal	Good	Very Good
Yield (kg/ha) June	300	400	560	750
Yield (kg/ha)	291	388	543	728
June producer's price (\$/kg)	0.05	0.04	0.04	0.04
Dec producer's price	0.06	0.06	0.05	0.04
Jun Revenue (\$/ha)	15.09	16.77	21.13	26.73
Dec Revenue (\$/ha)	18.30	22.54	28.46	30.50
Total package cost	1.26	1.26	1.26	1.26
Seed cost (\$/ha)	1.26	1.26	1.26	1.26
Seed quantity (kg/ha)	0.00	0.00	0.00	0.00
Seed price (\$/kg)	0.13	0.13	0.13	0.13
Storage cost	4.83	6.44	9.01	12.07
Tools and bags (\$/ha)	1.96	1.96	2.01	3.78
Hand tools (\$/ha)	1.47	1.47	1.22	2.20
Bags (\$/ha)	0.49	0.49	0.79	1.58
June Net income(\$/ha)	11.79	13.29	16.66	21.69
Dec Net income(\$/ha)	11.42	11.12	16.24	14.64
June Net income(\$/labor day)	0.10	0.11	0.14	0.18
Dec Net income(\$/labor day)	0.10	0.09	0.13	0.12

Source: Author's calculations

1 USD =MZM23,854 (IMF, 2004)

Note: Yield in December is 95% of the June yield due to pest losses and physical damages.

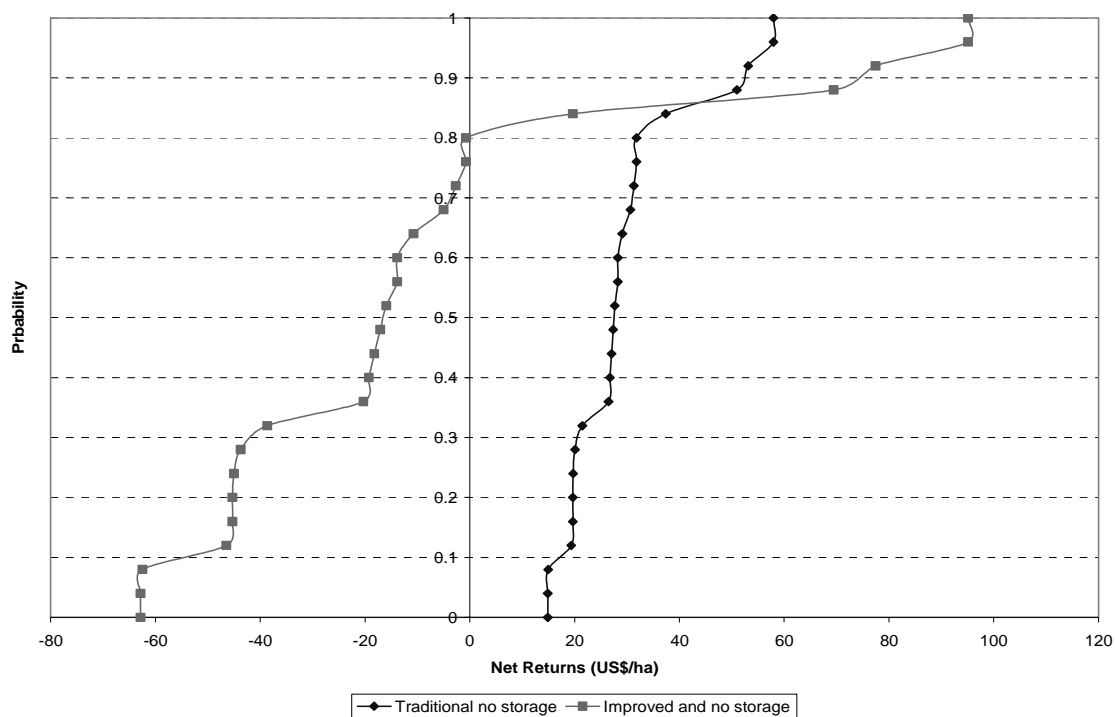


Figure B.1. Returns of Traditional Maize and Improved Technologies without Storage. Source: Author's calculations

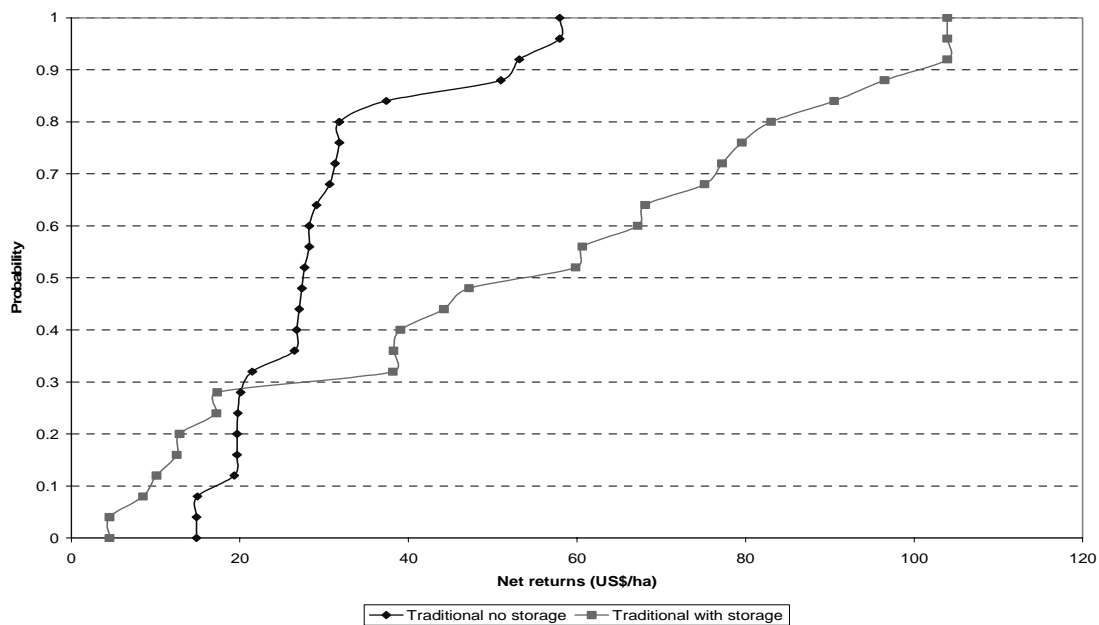


Figure: B.2 Returns of Traditional Maize Technologies with and without Storage. Source: Author's calculations

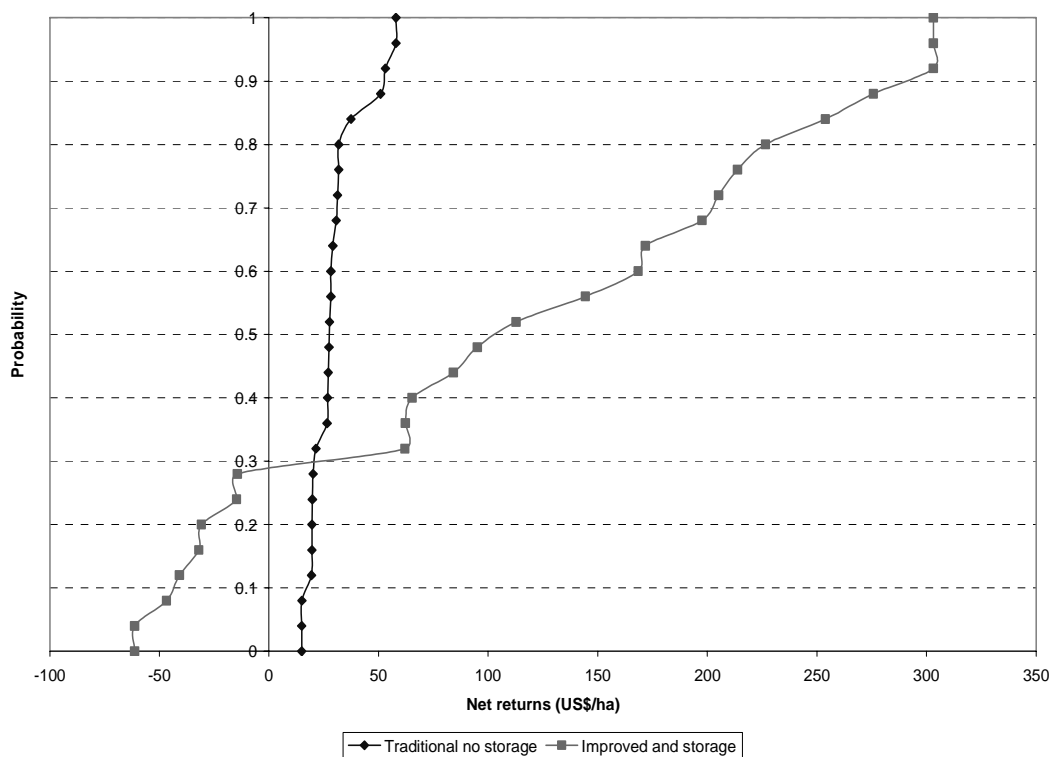


Figure B.3 Returns of Traditional Maize Technologies without Storage and Improved with Storage. Source: Author's calculations

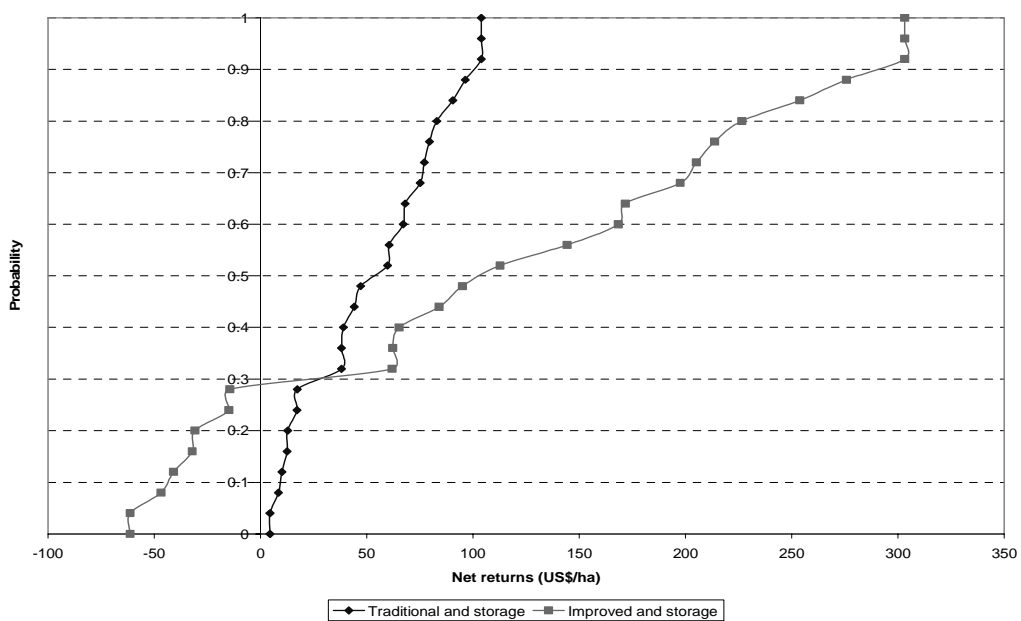


Figure B.4 Returns of Traditional and Improved Maize Technologies with Storage Source: Author's calculations

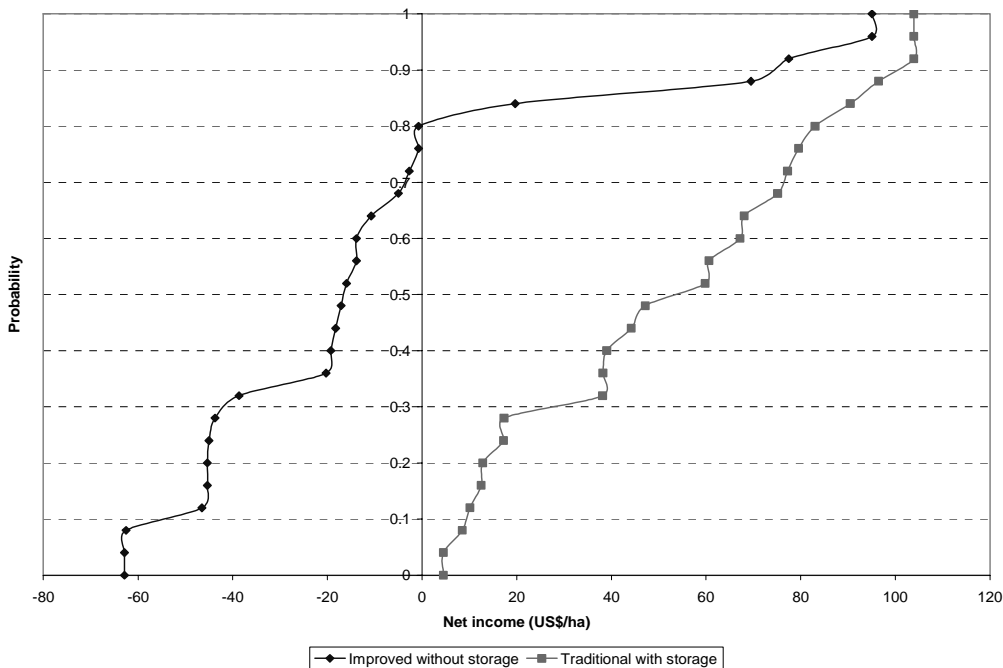


Figure B.5 Net Returns of Improved Technology Without Storage and Traditional maize Technologies With Storage. Source: Author's calculations

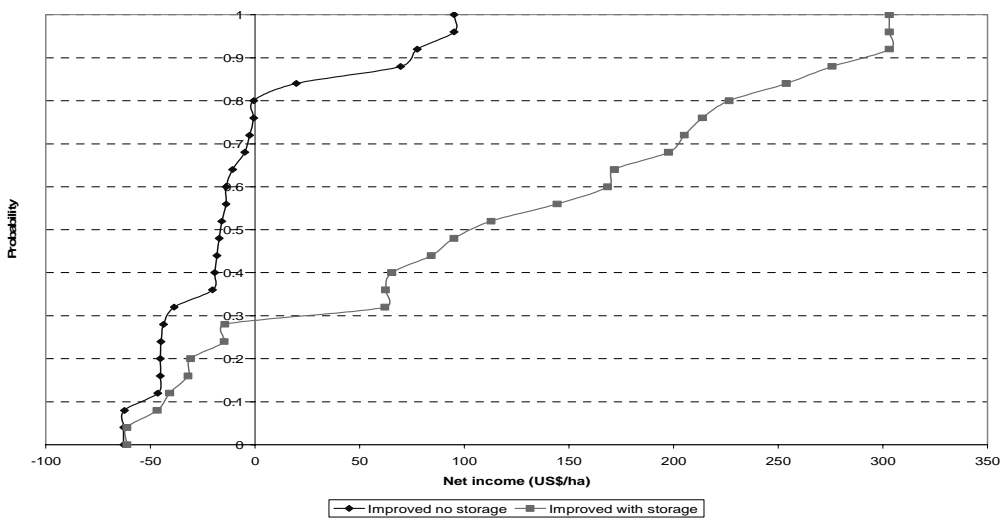


Figure B.6 Net Returns of Improved Technology with and Without Storage Source: Author's calculations

Table C.1 Maize Production in Mozambique (1992-2002)

Province	Production in Metric Tons										
	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	*01/02	
Total	533,083	526,361	734,000	947,000	1,042,025	1,123,658	1,336,078	1,019,034	1,143,263	1,235,657	
C.Delgado	40,359	45,063	78,000	81,000	62,222	97,409	57,265	50,104	70,444	105,565	
Niassa	87,017	79,481	133,000	163,000	175,625	173,508	144,568	121,641	134,327	178,633	
Nampula	54,095	41,173	86,000	101,000	117,229	120,410	129,197	106,995	107,479	111,582	
Zambezia	81,979	91,831	174,000	184,000	190,584	212,547	192,366	166,787	194,953	260,066	
Tete	83,265	45,305	36,000	92,000	125,677	125,282	177,544	139,986	151,078	177,798	
Manica	94,176	101,525	76,000	155,000	160,078	158,632	260,829	191,868	205,873	207,891	
Sofala	27,842	52,429	59,000	64,000	64,713	71,836	195,333	74,568	79,668	70,234	
Inhambane	22,936	37,751	49,000	65,000	47,911	59,806	104,466	83,022	75,921	40,014	
Gaza	16,825	23,772	23,000	27,000	61,159	74,050	38,811	53,728	66,215	51,343	
Maputo	24,589	8,031	20,000	15,000	36,827	30,178	35,699	30,335	57,305	32,532	

Source: SNAP (2002)

Table C.2 Sorghum Production in Mozambique (1992-2002)

Province	Production(Ton)										
	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	*01/02	
Total	65,615	97,532	113,075	139,075	180,218	191,069	186,087	151,387	313,787	314,136	
C.Delgado	6,800	7,145	10,000	9,000	9,559	14,144	14,386	12,115	36,931	49,910	
Niassa	1,578	904	2,000	2,000	2,876	2,526	2,354	2,271	29,146	28,203	
Nampula	13,987	18,413	20,000	24,000	27,556	26,959	24,311	22,321	79,058	83,933	
Zambezia	19,724	32,941	56,000	72,000	86,124	94,213	95,405	88,663	45,883	48,409	
Tete	39	17	0	0	144	97	134	146	31,115	29,119	
Manica	96	75	75	75	195	368	438	429	30,708	23,087	
Sofala	10,594	14,236	15,000	19,000	19,990	34,102	25,494	19,074	41,004	33,845	
Inhambane	912	929	2,000	2,000	2,201	1,847	1,754	1,589	13,172	11,259	
Gaza	7,746	21,090	4,000	7,000	24,543	10,867	16,989	1,981	6,290	5,744	
Maputo	4,139	1,782	4,000	4,000	7,030	5,946	4,822	2,798	480	627	

Source: SNAP (2002)

Appendix D: Farm Household Survey

Cereal Technologies and the effects of Marketing Strategies on farmers' income in
Mozambique
February-April 2003

1. Household identification

District	
Administrative Post	
Village	
Code the person interviewed	
Date of the interview	

Family members

Sex	Age	Highest level of education completed	Occupation

2. Crops cultivated in 2002/03

Crops	Total area	(%)
Maize		
Sorghum		
Millet		
Cowpea		
Peanuts		
Cassava		
Cotton		
Sunflower		
Other		

Field identification

Field number (machamba)	Soil type	Area	Crop
1			
2			
3			
4			
5			
6			

3. Expenditures last year

Expense	At Harvest period (June-August)		3 months after harvest (September-November)		At planting (December-February)		At Hunger period (Mar, Apr, May)	
	\$	Mode*	\$	Mode	\$	Mode	\$	Mode
Medical								
Clothing								
School fees								
Governmental Taxes								
Food								
Ceremonies (funeral, marriages, baptisms etc.)								
Others								

Mode* - Financing mechanism (cash, food for work etc)

Expenditure this year

Do you expect any changes in the expenditures this year? Yes No

If yes, fill the Table

Item	Change	Periods	Reasons

How much money (estimate) did you spend at harvest last year (cropping season)?

4. What are your sources of cash? (%)
- a. Sell of own-production -----
 - b. Informal marketing -----
 - c. Work off-farm -----
 - d. Remittances -----
 - e. Others -----

5. Can you estimate the revenue from these sources? (Meticais)

	Very bad	Bad	Normal	Good	Very Good
Sell of own-production -					
Informal marketing					
Work off-farm					
Remittances					
Others					

6. How do you invest your revenues?
- a. Buy improved seeds -----
 - b. Buy fertilizer -----
 - c. Pay taxes, governmental fees -----
 - d. Pay debts -----
 - e. Buy other foods -----
 - f. Social ceremonies -----
 - g. Others

7. Did you use improved seeds this season? Y/
Why?

7.1 If yes which: Maize -----Sorghum -----

7.2 Where did you buy it? -----

7.3 Was the season given to you by the extension agent? Yes or

8. Did you use fertilizer season? Yes

8.1 If yes, which one? -----

8.2 Amount of fertilizer used -----(kg)

8.3 Source of fertilizer -----

9. Agricultural Production

9.1 What is your total production in each type of growing season (kg, bags, tins?)

Crops	Very bad	Bad	Normal	Good	Very Good
Maize					
Sorghum					
Millet					
Cowpea					
Peanuts					
Cassava					
Cotton					
Sunflower					
Others					

10. Consumption

10.1 Do you keep a stock of grain for your own consumption after harvesting?

10.1 Amount of grain stocked in each state of nature (kg)

Crops	Very bad	Bad	Normal	Good	Very Good
Maize					
Sorghum					
Millet					
Cowpea					

10.2 How long does the stock last? (months)

Crops	Very bad	Bad	Normal	Good	Very Good
Maize					
Sorghum					
Millet					
Cowpea					

10.3 What portion of your harvest is sold? (%)

Crops	Very bad	Bad	Normal	Good	Very Good
Maize					
Sorghum					
Millet					
Cowpea					

2.2 What prices do you expect for this cropping season (2002/03)?

Crop	At harvest		6 months after harvest		At the hungry season	
	Price	Unit	Price	Unit	Price	Unit
Maize						
Sorghum						
Millet						
Cowpea						
Peanuts						
Cotton						
Others (specify)						

3. Other costs

3.1 Where is your major market for your agricultural products?-----

3.2 What is the cost of transport of a bag of 50 kg to that market?-----

3.3 What others marketing costs do you have to pay (example, market taxes)?-----

----- Specify.-----

Item	Amount	Period

Appendix E: Manica Household Model

Sets

c crops /maize, sorghum, Beans, cotton,cowpeas/

f(c) food crops /maize, sorghum, Beans, cowpeas/

cer(c) cereal /maize, sorghum/

n nutrients /calories, protein/

s states of nature /1*5/

st(s) states expc very bad /2*5/

*states (1-very bad, 2-bad, 3-average, 4-good, 5-ver good)

Act actividades /mz1, mz2, mz3, mz4, sh1, cwp,peas, ctn, bull, goats, fowls,nonag/

tec(Act) crop technologies /mz1,mz2,mz3,mz4, sh1, cwp,peas, ctn/

nc(Act) non crop activities /bull, goats, fowls, nonag/

* rum - small rumminants birds (chicken, ducks), nonag - off-farm activities

*mz1- maize traditional mz2- maize improved technology, sh1- sorghum traditional, sh2- sorghum improved, cwp-Beans, ctn-cotton

t time /Oct, Nov, Dec, Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep /

gs(t) growing season /Oct, Nov, Dec, Jan, Feb, Mar, Apr, May/

*gs is a substet of time and corresponds to the crop growing season

I tradable inputs /mseed1,mseed2, mseed3, mseed4, sgseed1, cpseed,peaseed,ctseed, NPK, urea, organo, pyrethro, glyco/

*mseed1 - maize tradional seed, mseed2- improved OPV without fertilizer, mseed3- maize improved seed+100 kg NPK, mseed4-improved seed +100 kg NPK, 50 Urea, sgseed1- sorghum traditional seed, sgseed2-sorghum improved seed,

*cpseed- cowpea seed, ctseed- cotton seed

in(I) input traded /mseed2, mseed3,mseed4, mseed5, cpseed,ctseed, organo, pyrethro, glyco/

;

* Yields are expressed in kg/ha

Table yield (tec,c,s)

	1	2	3	4	5
mz1.maize	250	500	700	850	1100
mz2.maize	500	750	950	1200	1500
mz3.maize	500	750	1200	2000	3750
mz4.maize	600	850	1500	2500	4100
mz5.maize	500	750	1750	2500	4200
sh1.sorghum	250	300	400	560	750
cwp.Beans	150	250	400	650	850
peas.Cowpeas	50	100	350	600	750
ctn.cotton	250	300	500	750	1200

;

* Prices at Harvest time MZM/kg

*maize 2100 1680 860 860 860 1260 1260

Table Harvprices (c,s)

	1	2	3	4	5
maize	2100	1680	1260	1000	960
sorghum	1400	1200	1000	900	850
beans	8625	8500	8000	7900	7500
cowpeas	3000	2750	2500	2250	2000
cotton	3000	3000	3000	3000	3000

;

* Average prices after harvest MZM/kg

*maize 2340 2340 2340 3500 2600

*maize 1800 1400 1250 2700 2400 1800 1550 3500 2600

Table croprices (c,s)

	1	2	3	4	5
maize	3500	2600	2000	1800	1550
sorghum	1700	1500	1400	1250	1000
beans	9000	8900	8650	8500	8000
cowpeas	3500	3250	3000	2750	2500
cotton	3000	3000	3000	3000	3000

;

* commodities are homogeneous ie, improved and traditional crops are priced equally

*ncreturns - Returns (in 1000 Mt) from non-crop activities in each state of nature

Table inuse(tec,I)

	mseed1	mseed2	mseed3	mseed4	Smseed5	sgseed1	cpseed	peaseed
mz1	30							
mz2		30						
mz3			30					
mz4				30				
Mz5					30			
sh1						10		
cwp							60	
peas								20
ctn								

	NPK	Urea	Organo	Pyrethro	Glypo
mz1					
mz2					
mz3	100				
mz4	100	50			
mz5	100	50		0.3	4
sh1					

```

cwp
peas          0.5
ctn           2      4
;
Table ncreturns (nc,s)
      1      2      3      4      5
bull  500000  750000  1000000  1500000  2000000
goat   375000  500000  750000  900000  1250000
fowls   5000   5000   5000    5000    5000
nonag  1500000 1500000 1500000 1500000 1500000

```

```

;
*Non crop returns in MZM/activity

```

TABLE LAND(t,tec) MONTHLY LAND USE BY ACTIVITIES

	mz1	mz2	mz3	mz4	mz5	sh1	cwp	peas
Oct								
Nov	1	1	1	1	1			
Dec	1	1	1	1	1	1	1	1
Jan	1	1	1	1	1	1	1	1
Feb	1	1	1	1	1	1	1	1
Mar	1	1	1	1	1	1	1	1
Apr	1	1	1	1	1	1	1	1
May	1					1	1	1
Jun								
Jul								

```

;
* Improved maize and sorghum are earlier maturing than the traditional crops

```

TABLE LABOR(t,tec) MONTHLY LABOR USE BY ACTIVITIES

	mz1	mz2	mz3	mz4	m5	sh1	cwp	peas
Oct	2	2	1	1	1			
Nov	1	2	1	1	1	1		
Dec	4	4	2	2	2	4	1	1
Jan	5	5	2	2	2	5	3	3
Feb	0	0	0	0	0	0	3	3
Mar	0	0	0	0	0	0	2	2
Apr	0	3	3	3	3	0	1.5	1.5
May	2					2	3	3

TABLE FLABOR(t,nc) MONTHLY LABOR USE BY NON CROP ACTIVITIES

	bull	nonag
Oct	0.5	25
Nov	0.5	25
Dec	0.5	25
Jan	0.5	25
Feb	0.5	22
Mar	0.5	25
Apr	0.5	25
May	0.5	24
Jun	0.5	25
Jul	0.5	24
Aug	0.5	25
Sep	0.5	24

;

*Nutritional information from FAO

Table a(ce,r,n) nutritional value of each crop per kg

	calories	protein
maize	3750	55.9
sorghum	3390	113

;

* minimum requirement of 2100 cal/day and 50 gr/day of protein

Table d(n,s) nutritional requirement per state of nature

	1	2	3	4	5
calories	3832500	3832500	3832500	3832500	3832500
protein	91250	91250	91250	91250	91250

;

scalars

hlabw wage rate MZM per day /30000/

*It assumed that the wage is constant throughout the year

liq cash available in MZM /1800000/

mininc minimum income requirement in MZM /2146000/

*1\$USD=24,000 (June 2003)

terra Total land available in ha /5.3/

Cereal minimum cereal consumption per hh per year /500/

store storage cost per kg per year /240/

r interest rate /0.30/

;

Parameters

* all ints in (1000 Mt/kg)

putcost(I) input costs /mseed1 1300, mseed2 20000, mseed3 20000, mseed4 20000, sgseed1 1200, cpseed 30000, ctseed 1000, NPK 800, urea 10000,organo 30000, pyrethro 50000, glyco 30000 /

*buy(cer) price of food /maize 2250, sorghum 2500/

* Food requirement is estimated at 2100-2500 calories/capita/day and 50 gram of protein/capita/day for a hh of 5 members

b(n) food requirement per year /calories 4562500, protein 91250/

hhp(f) household food price /maize 1300, sorghum 1200, Beans 8000/

Prob(s) likelihood of state occurrence /1 0.05, 2 0.20, 3 0.4, 4 0.30, 5 0.05/

* Adjusted states of nature (excluding the very bad state of nature

Probab(st) likelihood of state /2 0.21, 3 0.42, 4 0.32, 5 0.05/

incap(nc) /live 100000, nonag 2500/

*hcome(f) cereal minimum consumption in kg per year /maize 350, sorghum 150, beans 50/

Laboravail(t) labor available / Oct 50, Nov 50, Dec 60, Jan 57, Feb 51, Mar 53, Apr 51, May 51, Jun 51, Jul 51, Aug 51, Sep 54/

*mininc(s) minimum income requirement in '000MZM / 2 2000000, 3 2400000, 4 2750000, 5 3000000/

;

Positive variables

area(tec) hectares of crop i grown

oth(nc) units of other activities

owncons(cer,s) subsistence food in state of nature s

purch(cer,s) quantity of food purchased in state of nature s

latsales(c,s) quantity sold after harvest in state of nature s

hirelab(t) hired labor

Aglab(t) agricultural labor

consume(cer,s) - amount of food consumed in each state of nature s

croprod(c,s) total crop production in state of nature s

intot(I) total input used

income(s) net income post harvest sales and consumption in state of nature s

target(cer,s) cereal consumption per hh

Harvsales(c,s) Sales at harvest in state of nature s;

oth.up('nonag')=1;

oth.up('live')=8;

*harvsales.lo('maize',st)=100 ;

*harvsales.up('sorghum',s)=0;

*latsales.up('sorghum',s)=0;

*latsales.up('maize',s)=0;

*owncons.lo('maize',s)=50;

area.up('cwp')=1.0;

area.up('peas')=0.5;

```
*area.lo('sh1')=.5;
owncons.up(cer,s)=500;
purch.up(cer,s)=500;
```

Variables

```
income(s) income in each state of nature
ew expected income
;
```

Equations

```
objective
goal
come (cer,s) amount of cereal consumed
tar(cer,s) target cereal consumption
nb(n,s) nutritional balance (units)
produz (c,s) total crop production
inpuse (I) total input use
revenue(s) revenue
revenue1(s) revenue at harvest prices
revenue2(s)
Solo(t) land availability constraint in time t
labcons(t) labor availability constraint
lab(t) total labor available
liquid liquidity constraint
minincome(s) minimum income requirement
mincome
subs(s) minimum food in each state of nature
balance(c,s) identity constraint
balas sorghum identity constraint
balac Beans identity
Totwealth(s) total wealth
inventorycredit(s) inventory credit
fome
naglim
rumina
compra(s)
cerea
;
revenue1(s)..income(s)=e=sum((c),croprod(c,s)$ (ord(s)ne1)*harvprices(c,s))-
sum((I),intot(I)*putcost(I))*(1+r)+sum(nc,ncreturns(nc,s)*oth(nc))-
sum((cer),1.5*croprices(cer,s)*purch(cer,s))-sum(t,hirelab(t))*hlabw;
*revenue1(s)..income(s)=e=sum((c),croprod(c,s)$ (ord(s)ne1)*croprices(c,s))-
sum((I),intot(I)*putcost(I))+sum(nc,ncreturns(nc,s)*oth(nc))-
sum((cer),1.8*croprices(cer,s)*purch(cer,s))-sum(t,hirelab(t))*hlabw;
come(cer,s)$ (ord (s) ne 1)..consume(cer,s)=l= owncons(cer,s)+purch(cer,s);
```

```

*tar(cer,s)..sum(st,consume(cer,st)) =g=cereal;
nb(n,s)..sum((cer),a(cer,n)*(owncons(cer,s)+purch(cer,s))) =g= d(n,s);
produz(c,s)..croprod(c,s)=e=sum((tec),yield(tec,c,s)*area(tec));
balance(c,s)$ (ord(s) ne 1)..0=e=sum(cer,croprod(c,s)-owncons(cer,s)-harvsales(c,s)-
latsales(c,s));
inpuse(I)..intot(I)=e=sum(tec,inpuse(tec,I)*area(tec));
Solo(t) ..sum((tec),area(tec)*land(t,tec))=l=terra;
lab(t)..aglab(t)+hirelab(t)=e=sum(tec,area(tec)*labor(t,tec));
labcons(t)..aglab(t)+sum(nc,Flabor(t,nc)*oth(nc))=l=laboravail(t);
liquid..sum(t,hirelab(t)*hlabw)+sum((I),intot(I)*putcost(I))=l=liq;
fome..consume('maize','1')=e=0;
minincome(s)$ (ord(s) ne 1)..sum (c,harvsales(c,s)*harvprices(c,s))=g=mininc;
revenue(s)..income(s)=e=sum((c),croprod(c,s)$ (ord(s) ne 1)*croprices(c,s))-
sum((I),intot(I)*putcost(I))*(1+r)+sum(nc,ncreturns(nc,s)*oth(nc))-
sum((cer),croprices(cer,s)*1.5*purch(cer,s))-sum(t,hirelab(t))*hlabw-
sum(c,latsales(c,s))*store*(1+r);
revenue2(s)..income(s)=e=sum((c),croprod(c,s)$ (ord(s) ne 1)*mcroprices(c,s))-
sum((I),intot(I)*putcost(I))+sum(nc,ncreturns(nc,s)*oth(nc))-
sum((cer),mcroprices(cer,s)*1.75*purch(cer,s))-sum(t,hirelab(t))*hlabw-
sum(c,latsales(c,s))*store;
objective..ew=e=sum(s,prob(s)*income(s));
*objective..ew=e=sum(s,prob(s)* sum((c),latsales(c,s)$ (ord(s) ne 1)*harvprices(c,s))-
sum((I),intot(I)*putcost(I))+sum(nc,ncreturns(nc,s)*oth(nc))-
sum((cer),croprices(cer,s)*1*purch(cer,s))-sum(t,hirelab(t))*hlabw);
;
Model Manicaa/objective,liquid, inpuse, produz,solo, nb,come, minincome, balance,
lab,labcons, revenue/;
Model Manicab/objective,liquid, inpuse, produz, solo,nb,fome, come, balance,
lab,labcons, revenue/;
Model Manicac/objective,liquid, inpuse, produz,solo, balance, lab,labcons, revenue1/;
Solve Manicaa using LP maximizing ew;
Display ew.l, harvsales.l, harvsales.m, latsales.l, latsales.m, owncons.l, purch.l,
owncons.m, purch.m;
*,
Parameters
hincome /1 /
tincome(s) /1 1, 2 1, 3 1, 4 1, 5 1/
harvin(s) /1 1, 2 1, 3 1, 4 1, 5 1/
sold(s) /1 1, 2 1, 3 1, 4 1, 5 1/
Eincome(s)/1 1, 2 1, 3 1, 4 1, 5 1/;
harvin(s)= sum(c,harvsales.l(c,s)*harvprices(c,s));
tincome(s)=income.l(s)+harvin(s)+ sum(cer,owncons.l(cer,s)*harvprices(cer,s));
*Eincome(s)=sum(c,prob(s)*income.l(s)+harvin(s)+
sum(cer,owncons.l(cer,s)*harvprices(cer,s)));

```

```

hincome=sum(s,                                prob(s)*income.l(s)+
harvin(s))+sum((cer,s),owncons.l(cer,s)*croprices (cer,s));
sold(s)=sum(c,produz.l(c,s)-harvsales.l(c,s));
Eincome(s)=prob(s)*(income.l(s)+sum((c,harvsales.l(c,s)*harvprices(c,s))+sum(cer,c
roprices(cer,s)*purch.l(cer,s))+ sum(cer,owncons.l(cer,s)*harvprices(cer,s)));
display tincome, hincome, harvin, sold, Eincome, area.l, oth.l, purch.l;
display tincome, hincome, harvin, sold, Eincome, area.l, oth.l, purch.l;

```