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Introduction of New Agricultural Technologies and Marketing Strategies in Central Mozambique

by

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SUMMARY

Low output prices are disincentives to agricultural technology adoption in central Mozambique. Marketing strategies that enable farmers to sell after the post harvest price collapse and programs to expand food processing to moderate the between year price collapses are necessary to make new maize technologies sufficiently profitable for farmers to adopt them. This paper analyzes the effects of marketing strategies on the adoption of new maize technology and on farmers' income.

Crop partial budgets and a household farm model were used to estimate the effects of the various combinations of technologies and new marketing strategies. The marketing strategy objectives are to exploit the seasonal price increase and in good years moderate the price collapse. Inventory credit and market expansion policies were tested individually and in combination.

Crop budgets indicate that new technologies are not profitable at harvest prices. The farm model results suggest that without new marketing strategies, adoption of new technologies will not occur. The profitability of new technologies is significantly enhanced by marketing strategies. Increased profitability of new technologies leads to increased adoption and increased farm household expected income. These results indicate that the use of new improved cultivars and fertilizers can be accelerated if farmers can exploit for their benefit the seasonal price variation by selling when the prices recover. Pooling, storage and inventory credit are part of the strategy. The model results indicate that if inventory credit were available, new technology would be adopted with a consequent increase in farm income. The high returns to capital invested, with a shadow price of capital of 82%, indicates a further potential dynamic effect for farmers to reinvest their increased profits in new technologies in the following crop year. Over time, then, the income effect would be even larger as farmers respond to the high potential returns of further investments once the adoption process is underway.

Key words: Central Mozambique, new technologies, adoption, inventory credit, household farm model

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ACRONYMS

ACDI/VOCA	Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance (US Based Private Nonprofit Organization)
FAOSTAT	FAO statistical database
IIAM	Institute of Agricultural Research of Mozambique
IMF	International Monetary Fund
INAM	National Institute of Meteorology
INE	National Statistics Institute
INIA	National Agronomic Research Institute
MZM	Mozambican meticais (currency)
NGOs	Non-governmental Organizations
OPV	open pollinated varieties
PAN	FAO Special Program
SG2000	Sasakawa Global 2000
SIMA	Mozambican Agricultural Market Information System
SPER-Manica	Manica Province Rural Extension Service
UCAMA	Manica Small Farmers Union

INTRODUCTION OF NEW AGRICULTURAL TECHNOLOGIES AND MARKETING STRATEGIES IN CENTRAL MOZAMBIQUE

1. INTRODUCTION

1.1. Background

Maize is the principal domestically produced food staple in Mozambique. Maize is thus important as it helps to achieve food security and it is important in the livelihood of the people in rural areas. The growth in maize production through enhanced agricultural productivity in Mozambique will stimulate growth in other economic sectors, with which agriculture has deep linkages.

Currently, Mozambique lags behind all other East and Southern African countries in maize productivity. In 2004 its maize yield averaged 960 kg/ha compared to 1500 kg/ha for Kenya, 1100 kg/ha for Malawi, and 2600 kg/ha for South Africa (FAOSTAT 2005). These low yields are a reflection of Mozambique's limited use of irrigation and of yield-enhancing inputs such as fertilizers and improved seeds.

Agricultural technological change is urgent in Mozambique if the country is to achieve the goals of reducing poverty. Technological change can help reduce poverty directly by raising the welfare of poor farmers who adopt the technological innovation. Potential benefits can be through increased production for home consumption, more nutritious foods, and higher gross revenues from sales derived from both higher volumes of sales and higher unit value products, lower production costs, lower exposure to yield risks, lower exposure to unhealthy chemicals, and improved natural resource management. The indirect effects on poverty reduction include the effects on food prices, the employment and wage effects in agriculture and other sectors with linkages to agriculture.

In spite of numerous agricultural research and extension activities of the public sector and various Non-governmental Organizations (NGOs) new cereal technology introduction has been minimal in central Mozambique. The region is characterized by good rainfall but low to medium soil fertility. Increased agricultural production will require increased use of improved cultivars and fertilizer. The agricultural research and extension efforts indicate that farmers can significantly increase cereal, particularly maize, yields through the application of the recommended improved seed and fertilizer package. The central issue however is how to get diffusion of new technologies and specifically, what are the effects of higher output farm-gate prices, as a result of marketing strategies, in the adoption of new technologies?

1.2. Justification and Objectives

Contrary to the commonly held belief that technology adoption is constrained by the lack of liquidity and or farmers' risk aversion, our hypothesis is that adoption of new technologies is principally constrained by low profitability of the technologies due to low expected output price. 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. Sanders, Shapiro, and Ramaswamy (1996) recognized that price collapses by reducing expected incomes and increasing income variability, can be a principal disincentive to adopting new technologies.

This paper presents a quantitative assessment of the potential farmers' benefits from increases in the productivity of the agricultural sector combined with the introduction of new marketing strategies. The analysis is based on farm-programming models designed to capture the important structural features of farm household decision making in Mozambique. The model explicitly incorporates the harvest income target and satisfaction of household caloric demand through home-consumption of own production before maximizing cash revenues through marketed goods.

1.3. Organization of the Paper

The remainder of the paper is organized as follows: Section 2 makes a brief presentations of new agricultural technologies in central Mozambique and illustrates the problem of price collapse. The farm-programming model used in the analysis is presented in Section 3, while Section 4 presents results and discussion. The last section presents conclusions and policy implications.

2. NEW AGRICULTURAL TECHNOLOGIES IN CENTRAL MOZAMBIQUE AND PRICE VARIATION

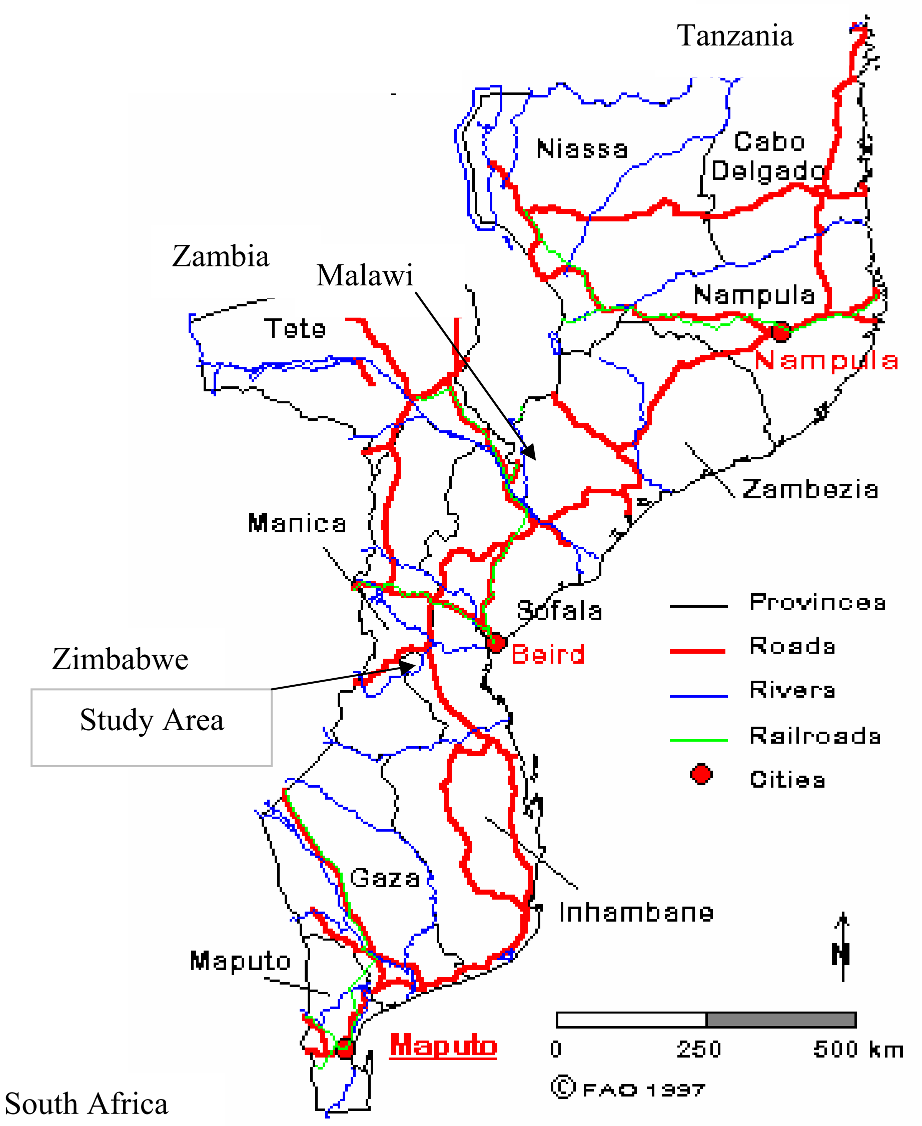
2.1. Agricultural Technologies

New sorghum technologies were not able to improve yields of traditional sorghum cultivars due to early maturity. The early maturity led to increased bird attack, head bug, and mold complexes. In contrast, new maize seed and fertilizer based technologies represent an important improvement over the current maize practices. Open pollinated varieties, hybrids, and fertilizer levels have been introduced by NGOs, government extension and seed companies' demonstration plots as well as on-farm trials. A number of farmers have had access to these new technologies through emergency programs or through development programs such as Sasakawa Global 2000 (SG2000), FAO Special Program (PAN), and others. Several white, open pollinated cultivars and hybrids including quality protein maize (Sussuma) developed by public and private institutions are available for farmers, but their adoption is still limited.

Although the majority of farmers still grow local varieties, there is an increasing demand for improved inputs such as seeds of new cultivars and fertilizers. Farmers obtain seeds from various sources. Farm interviews in central Mozambique (Figure 1), indicate that 60% 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 open pollinated varieties (OPV) or hybrids from input shops. Some farmers, especially in the district of Manica, close to the border, bought maize hybrids and OPV seeds from neighboring Zimbabwe (Uaiene 2004).

The local varieties include a group of varieties that have been locally adapted or selected. The local varieties are sourced 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. Local varieties are tall with white large grain, good poundability, and resistance to weevils. Improved cultivars include hybrids and OPVs. A large number of improved white maize cultivars and hybrids adapted to different agro-ecological environments are available for farmers in central Mozambique. Consistently, these improved cultivars and hybrids have out yielded the traditional cultivars.

Figure 1. Map of Mozambique Showing the Study Area



Soil fertility practices followed by farmers in Manica province include: chemical fertilizer and livestock manure incorporation; fallowing; use of livestock manure; crop rotation (beans/cowpeas and maize); incorporation of stover and grass; avoiding burning of grass; and intercropping.

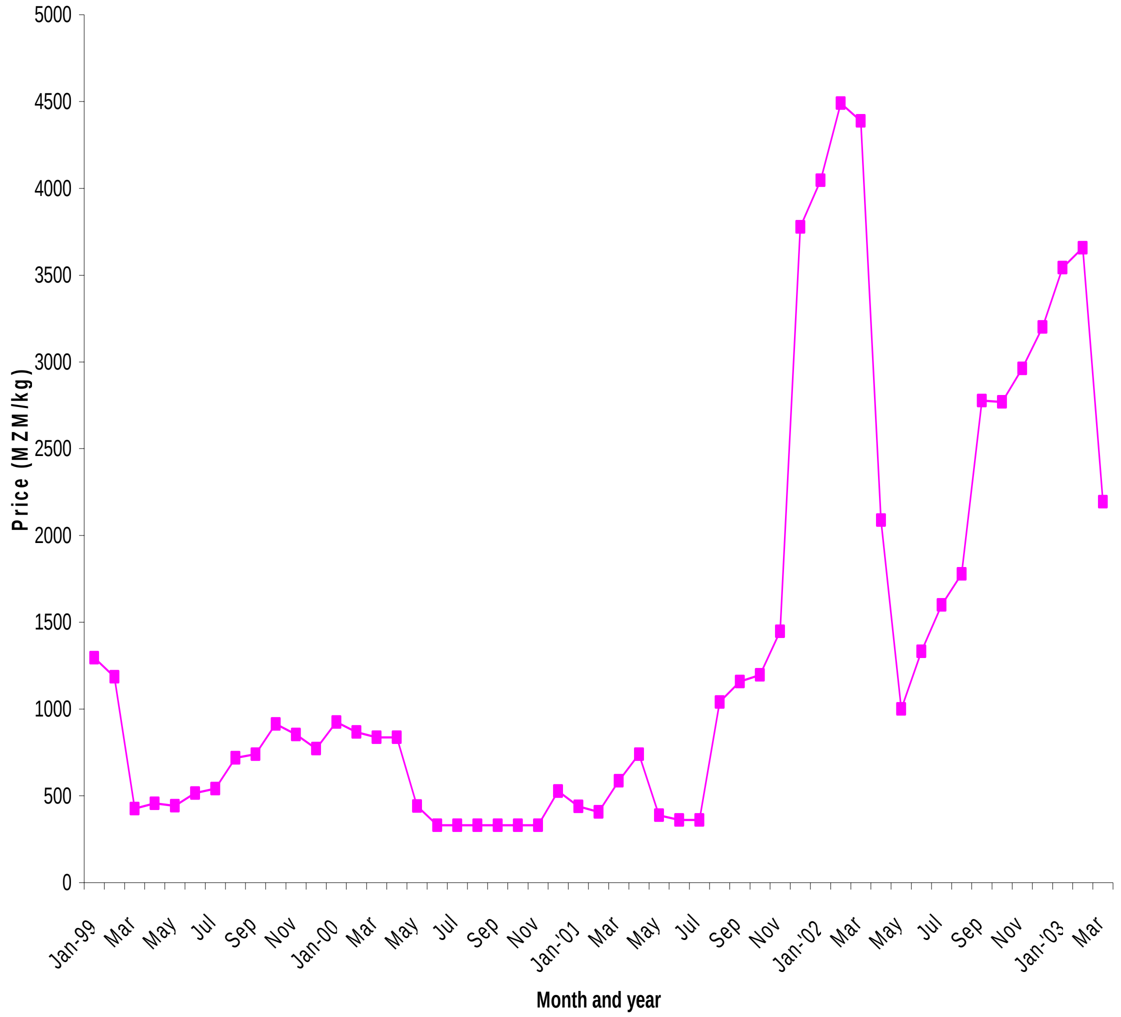
The dominant crops in the agricultural maize-sorghum farming system in Manica are maize, sorghum, beans, and cotton. Other crops such as millet, sesame, and sunflower are grown in small areas. These crops are not included in our representative farm model because they do not produce enough quantities to factor significantly into a representative farm model. The crop combinations consist of sole crops.

2.2. Maize Price Variation

Mozambique has an agriculturally based economy. A central feature of this economy is very high risks including: production failure and high price variation. There is a low price immediately after harvest, high prices in years of bad harvest, and usually a price collapse at bumper harvests.

The maize price trends for the region are presented in Figure 2. The price data reveal large seasonal and inter-annual price variation. There is large variation between the highest and the lowest prices which is explained by the price fluctuation between harvests. Prices generally decline immediately after harvest and are at their lowest around May-June. In this period the farm household liquidity constraint may force the household to dispose of their grain at low prices principally at harvest. At harvest farmers need money to repay loans incurred during the crop season, to pay family labor that helped in the production activities, school fees, taxes, and ceremonies such as naming and weddings. The income requirement at harvest make farmers shift from net sellers at harvest to net food buyers later when the prices are higher, even in good harvest years (Barrett 1996; Weber et al. 1988).

Figure 2. Maize Real Producer's Price Trends Deflated by CPI (INE 2004) in Chimoio



Source: SIMA (2003)

The price differences between the period after harvest, when the prices are at the lowest point, and six months after harvest, when the prices are at the highest level, indicate the potential benefits to an inventory credit program. A study of maize-fertilizer based technology disseminated by extension in central Mozambique concluded that storing maize for several months instead of selling immediately after harvest dramatically increased farmer gains (Howard et al. 1999). The study reports that 89% of farmers selling at December prices made profit.

The increasing price variability from both the demand and supply side is manifested in seasonal and inter-annual fluctuations in price levels both of which have welfare consequences. Price collapse resulting from the production increases due to good rainfall years produce income shocks especially for households with low asset base. Development of new maize markets is expected to increase demand and reduce price collapse and, therefore, stimulate rapid adoption of new agricultural technologies.

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.

The model developed here analyzes potential gains to marketing interventions. First, by selling six months after the post harvest price collapse; second the expansion of the processing demand for food and feed; third, a modification by the public sector of policies that drives down the prices of agricultural products in bad rainfall years; and finally the combination of all three marketing interventions.

3. THE HOUSEHOLD MODEL

The conceptual framework used in this study 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. The important factors in farmer decision making considered here are: the household harvest income requirement; the food subsistence objective; and liquidity constraints. These factors are expected to be of principal importance in farmers' decision making about new technologies.

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. Harvest time income seems to be even more important than setting aside subsistence food as indicated by food sales even in bad years. In the very bad state of nature, food aid is expected. So the very bad state of nature is excluded from consideration in the calculation of the expected yield distributions. The simultaneous satisfaction of both constraints (harvest income and the minimum food consumption target) may be infeasible in bad states of nature. Both goals are part of the rural household risk management strategies. Similar approach was used by Sidibé (2000); Vitale and Sanders (2005); Abdoulaye (2002); and Abdoulaye and Sanders (2005).

The farm household harvest income and food constraints are satisfied using own crop production. Four of the five states of nature† are considered in the model. The very bad state of nature is not considered because the yield expectation in such a state is very low such that the household seeks outside assistance for subsistence.

The farm household problem is represented mathematically as follows:

Maximize:

$$E(W) = \sum_{s=1}^{5} \rho_S w_s \tag{1}$$

Subject to:

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

$$\sum_i \sum_s P_{1is} q_{1is} \geq \bar{I} \tag{3}$$

$$C_{is} + q_{1is} + q_{2is} = Q_{is} \text{ for all i} \tag{4}$$

$$\sum_i a_{ijm} * x_{im} + \sum_t a_{tjm} * x_{tm} \leq b_{jm} \text{ for all j} \tag{5}$$

$$Q_{is} = \sum_i y_{is} x_i \text{ for all s} \tag{6}$$

$$w_s = \sum_i p_{2is} q_{2is} + \sum_i r_{ts} x_t - \sum_i c_i x_i - \sum_i r_{2is} q_{2is} - \lambda \sum_i p_{2is} B_{is} \tag{7}$$

$$w_s^* = w_s + \lambda p_{2is} \tag{8}$$

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* See Uaiene (2004)

† The five states of nature are very bad, bad, normal, good and very good. See definition in Table A1 and the maize grain yield in Table A2 in the annex .

$$\sum_s \rho_s (w_s + (\sum_i p_{1is} q_{1is}) + p_{cs} C_{is}) = \psi \quad (9)$$

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
s – States of nature
t – Other activities

w_s - Income value post harvest sales plus the net returns from other activities

w_s^* - Total household income from agricultural and non-agricultural activities

q_{1is} –Quantity of crop 1 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} -Post harvest price (MZM/kg) and quantity (kg) sold respectively for crop i in period 2 in the state of nature s

$\bar{I}$ - Minimum income (MZM) required at harvest

a_{cn} – Nutrient (calories and protein) content for each cereal

C_{is} – Quantity in kg of cereal good i for own-consumption in the state of nature s

B_{is} – Quantity in kg of crop i purchased for home consumption in the state of nature s

Q_i – Total production in kg of crop i

x_i - Land area in ha used for crop i

x_t - Level (units) of non-crop activities

y_i - Yield in kg/ha of crop i

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

c_i – Cost per unit area (MZM/ha) of producing crop i

λ - Premium farmers pay when buying food in period 2

Ψ - Expected total income (MZM)

$a_{ij,}$ - Technical coefficients for crop activities (amount of resource j for crop i)

a_{tj}– Technical coefficients non crop activities (amount of resource j for activity t)

d_n – Minimum requirement of nutrient n

b_{jm} - Availability of resource j (e.g. capital, labor) in period m

r_t - Return from non-agricultural activities t

r_{2i} – Storage cost (MZM/kg/month) for crop i

Equation 1 represents the objective function which maximizes expected income over the states of nature and it is a function of post harvest income after food purchases are deducted (Equation 7) and the probability of each state of nature. There are five states of nature: very bad; bad; normal; good; and very good. The probability for each state of nature was estimated as 0.05; 0.20; 0.40; 0.30; and 0.05 respectively. Household nutrient requirements (Equation 2) are obtained from own food production and food that the household buys from the market. Following the FAO human nutrient requirement estimates, 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 3 represents the harvest income goal. Equation 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 5. Equation 6 indicates the production function. The amount produced is a multiplicative function of yield and the optimal area allocated. Equation 7 defines the post harvest income maximization. Equation 8 defines the household income received six months after harvest in each state of nature by excluding the expenditures on food. Equation 9 recovers the total household income (the value of home consumption, 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.

Four variants of the model are tested in order to determine which is best able to predict the observed cropping system in central Mozambique, the target area of our study and a prime maize and 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) the harvest income goal and then income maximization; and d) both food and harvest income constraints and then income maximization.

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 (Uaiene 2003). This value represents the average cash expenditure of three districts surveyed in a normal year. Although it is likely that in practice farmers would adjust the harvest income for each state of nature, we did not adjust the harvest income goal for different states of nature.

4. RESULTS AND DISCUSSION

4.1. Improved Technologies without Market Strategies

The net returns of improved maize and fertilizer based technologies are only higher than the traditional practices when sales are made six months after harvest as indicated in Table 1. The increased seed and additional fertilizer costs are not offset by increase in yield if sales follow harvest. By selling six months after the post harvest price collapses there are substantial differences in prices (Figure 3) which makes the introduction of new maize improved cultivars and fertilizer profitable as shown by partial budgeting analysis presented in Table 1.

Maize, sorghum, beans, cowpeas, and cotton as well as livestock and nonagricultural activities are all part of the model's variants results (Table 2). Due to pest problems farmers are known to place a limit on the land allocated to beans and cowpeas. Our modeling exercise placed an upper limit of 0.5 ha for both beans and cowpeas.

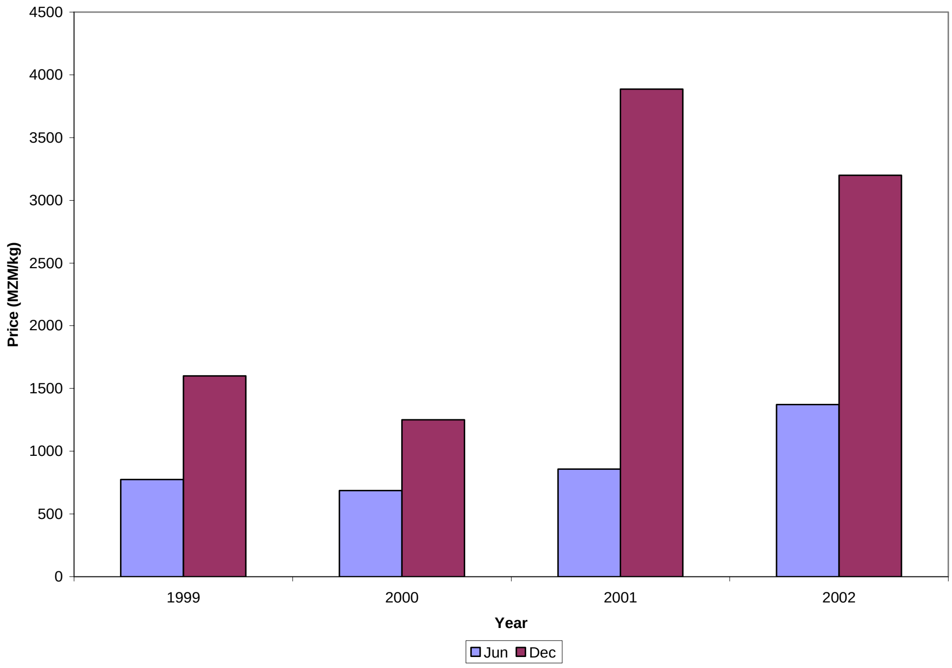
In spite of the existence of new technologies in the region, none of the four model results includes new maize technologies in the optimal solution. Even when the farmer's objective is profit maximization without the two constraints, the new maize-fertilizer based technologies available to farmers in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

Table 1. Partial Budget Analysis of Maize with 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-ay/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

Figure 3. Maize Producer's Price Variation between June and December in Manica (1998-2002)



Source: SIMA (various years)

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.

Table 2. Base Model Results (ha) of the Average Farmer's Optimal Crop Mix

Activity	Model variant				
	Farmer's observed practice[a]	A	B	C	D
Traditional maize no fertilizer	3	2.6	2.6	3.2	3.2
Improved maize + NPK[b]	0.5	0	0	0	0
Traditional sorghum	0.5	0	0	0.5	0.5
Beans	0.2	0.2	0.2	0.4	0.4
Cow peas	0.3	0.5	0.5	0.5	0.5
Cotton	1	2.2	2.2	0.9	0.9
Expected income (US $)	335	496	465	397	357
Shadow price of 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

Field surveys (Uaiene 2003; 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 2).

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; Sidibé 2000), as well as farmers' behavior in bad years.

The farm model results are consistent with the observed 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 as maize grain is sold at harvest.

The next section 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 the adoption of new maize technologies.

4.2. Marketing Strategies

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

Table 3. Maize Prices (MZM/kg) for Different States of Nature and Policy Intervention Scenarios

	State of Nature					
	V. Bad	Bad	Normal	Good	V. Good	
Probability	0.05	0.20	0.40	0.30	0.05	
Intervention			Price			Exp. price
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.

adverse weather years. In the simulation, we assume that this price depressing effect would be reduced. Public policy makers would give more emphasis to farmers making money.

Table 3 shows the effect of different marketing strategies on the price of maize. In each state of nature the prices without new policy reflect the current situation in which most of the grain is sold at harvest. The price of the inventory credit is the average price six months after harvest. 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.

The expected price, which is a weighted average of the price in each state of nature, 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/kg) for the inventory credit and good year moderation of price collapse and MZM2206/kg ($0.09/kg) 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 the depressing effects of public price stabilization policies are moderated, the price level can be 40% higher.

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 4). 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 4 indicates that 1.5 ha is allocated to the new maize cultivar and fertilizer resulting in

Table 4. 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%

Source: Model results

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, especially for maize production in central Mozambique. This also confirms our earlier hypothesis that new marketing strategies would encourage a more rapid introduction of new agricultural technologies.

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 were 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 high 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 consideration in the calculation of the income. The probability of each one of the four remaining states of nature, after excluding the very bad state of nature, is recomputed and is presented in Table 5 below. Household income in each state of nature with and without inventory credit is given in Table 5. The sum of the probability of the new sub-set of states of nature sums to 1. Given the expected farmer's output price gains from the inventory credit, the 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. With inventory credit the highest increase in income (106%) is observed in the bad state of nature, since in these years this is the largest seasonal price variation.

Currently there are no active inventory credit programs operating in Mozambique 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 the 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 farmers' associations in Mozambique 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.

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

4.3. 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 attractive for international food aid. In contrast 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.

Table 5. 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

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

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 drives the producer price down. Data from the Mozambican Agricultural Market Information System (SIMA) (2003) indicated that the price of maize in Manica has fallen by more than 50% with the arrival of food aid.

A model simulation assuming a 50% increase in the normal prices during bad years combined with inventory credit showed no change of crop mix compared to the inventory credit alone. However, this price moderation in bad years accompanied by inventory credit led to a 68% increase in income compared to the without inventory credit scenario.

4.4. 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. 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.

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 farmers' income as indicated by column D. Combining inventory

Table 6. Land Allocation and Income Effect of Price Policies

	Model				
Technology	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
1 USD =MZM23,854 (IMF 2004)

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. When new maize technologies are adopted, traditional sorghum disappears both in the model and in our field observations.

Combining all three marketing strategies there is an 81% income increase above the current system (Table 6). 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) 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 Tables 5 and 6. 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.

The expected income for each marketing strategy varies with state of nature as indicated in Table 7. In none of the states of nature does the farmer's income get worse than the "status quo". The farmer does not increase his or her risk level for participating in one or combined marketing strategies. 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.

Table 7. Household Incomes ($) for Different Marketing Strategies

	Marketing Strategy				
State of nature	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

5. CONCLUSIONS AND POLICY IMPLICATIONS

The objective of this paper was to examine the interaction of new maize technology and marketing strategies on the farm household income. No attempts are made to analyze the sector-wide or economy-wide welfare implications of the policies proposed. Marketing strategies allow an improvement in the output price received by farmers, the adoption of new cultivar-fertilizer based technology and consequently an improvement in their income.

The results of this paper draw attention to the importance of the demand side as government and non-governmental organizations in central Mozambique 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.

By accessing improved agricultural technology, small farmers can play a major role in increasing food availability close to where it is most in need, raising rural incomes, expanding employment opportunities and contributing to a growth in exports.

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 increased farmers' income.

A critical and, perhaps, controversial issue is the dilemma to ensure that farmers receive higher producer prices for their output on one hand and the government desire to keep food prices low for the net food buyers on the other, especially through food aid imports. It is important to ensure that food aid imports are not providing a 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 local purchases of maize for use in the emergency food distribution programs. This may provide incentives to adoption of new technologies which will allow increase in maize supply and enable farmers to profit from the utilization of new agricultural technologies in the prime agricultural area such as central Mozambique.

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ANNEX

States of Nature and Crop Yields

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 A1. 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 A1. Rainfall (Quantity and Distribution) and Associated States of Nature

		Rainfall Distribution	
Rainfall Quantity	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). Crop yield were calculated from on-farm trials conducted by INIA and SPER-Manica.

Table A2. Expected Yields (kg/ha) of Activities per State of Nature

	States of Nature				
Activities	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