MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

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Research Paper Series

Comparing Yields and Profitability in MADER's High- and Low-Input Maize Programs: 1997/98 Survey Results and Analysis

by

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Research Report No. 39
March 2000

Republic of Mozambique

DIRECTORATE OF ECONOMICS

Research Paper Series

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ACKNOWLEDGMENTS

The Directorate of Economics is undertaking collaborative research on food security with Michigan State University's Department of Agricultural Economics.

We wish to acknowledge the financial and substantive support of the Ministry of Agriculture and Rural Development of Mozambique and the United States Agency for International Development (USAID) in Maputo to complete food security research in Mozambique. Research support from the Bureau for Africa and the Bureau for Global Programs of USAID/Washington also made it possible for Michigan State University researchers to contribute to this research.

This study could not have been completed without the unstinting assistance we received from many individuals, especially the farmers who permitted us to measure field areas, collect crop samples for yield estimation, and subject them to long interviews. We are grateful to them and to the survey supervisor, interviewers, driver and data clerks listed individually on the following pages. We would also like to thank Mr. Vittorino Xavier, Director of Agriculture in Nampula Province, senior extension and research staff in Nampula Province, and Prof. Jim Oehmke of MSU for their suggestions which improved the quality of field research and analysis undertaken in this paper. The final views expressed here are those of the authors and do not necessarily reflect the official position of the Ministry of Agriculture and Rural Development nor of USAID.

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EXECUTIVE SUMMARY

Introduction and Objectives

Mozambique, one of the poorest countries in the world, must increase agricultural productivity to feed its growing population and spur economic recovery following years of civil war. Agricultural intensification is one way to increase productivity, but the use of technologies such as improved seed and fertilizer is extremely limited.

The Department of Rural Extension (DNER) in the Ministry of Agriculture and Rural Development (MADER) operates several programs to stimulate maize production through the use of improved technologies in Mozambique's high-potential regions. Until recently no formal analysis had been carried out to assess the yield performance and profitability of the improved technology packages. In 1996/97 the Department of Policy Analysis (DAP) in MADER's Directorate of Economics began a three-year study of yields and profitability in alternative maize intensification programs in collaboration with DNER. This paper summarizes the results from data collected during the study's second year, 1997/98. The analysis is based on a sample of 210 smallholder farmers in Nampula Province using three different sets of production practices: (1) the DNER/Sasakawa-Global 2000 Program (DNER/SG) high-input package (improved open-pollinated maize, 100 kg/ha each 12-24-12 and urea fertilizer on credit), (2) improved planting and weeding practices only (using local seed, without fertilizer); and (3) a control group of farmers using traditional practices (no improved seed or fertilizer).

The objectives of the research were to: (1) describe the characteristics, input use patterns and yield response by group; (2) analyze the relative contribution to yield of the different technologies, environmental factors, and management practices; and (3) assess the profitability of the three different technology types at the farm level. We estimated econometric yield models to quantify the effects of key inputs and field practices on productivity. Financial budgets were constructed to assess the farm-level profitability of improved maize technology use.

Key Findings: Yield Results and Determinants

Average yields in the 1997/98 season ranged from 1.4 tons/ha for control group members (traditional practices, no purchased inputs) to 1.7 tons/ha for improved management only farmers (no purchased inputs) and 2.0 tons/ha for high-input farmers. Yields for all groups exceeded average yields for Nampula Province in previous years by a wide margin. Provincial averages were 0.8 ton/ha in 1994/95, 0.9 ton/ha in 1995/96 and 1.0 ton/ha in 1996/97. Our analysis of socioeconomic characteristics indicated that sample farmers are not significantly better off in terms of resources than average farmers in Nampula Province. The relatively high sample yields for farmers using no improved inputs (compared to provincial averages) suggest that the sites included may have relatively better cropping conditions than other areas in the province. Therefore it will be important to use caution in generalizing from these findings to areas where agroecological conditions are less favorable.

Although average high-input yields exceeded improved management only and control group yields across the sample, when the results are disaggregated by region they reveal that high-input yields are significantly higher than improved management yields only in Monapo/Meconta Districts (Region 8). Average high-input yields in Region 8 were 2.7 tons/ha, compared to 2.0

tons/ha for improved management only farmers and 1.8 tons/ha for control group members. Differences between groups in Regions 7 and 10 were not statistically significant.

Despite this apparent evidence of poor average performance from high-input technology, our econometric analysis of yield determinants revealed a very strong and positive relationship between higher yields and the use of improved seed and fertilizer together with increased plant density. The results suggest that high-input maize technology holds considerable potential for increasing yields, but the performance of the improved input package in 1997/98 may have been compromised by poor program implementation. In two of three regions, improved seed and fertilizer were delivered late and subsequently delayed planting by 2-5 weeks. The results also show that use of high-input technology is riskier (i.e., yields are less stable) than low-input or traditional methods. This is an especially important consideration if high-input technology is extended to farmers in more marginal agroecological areas or with fewer household resources for whom a yield loss in one season could be catastrophic.

The analysis indicates that increasing plant density is critical to improving yields of high-input maize. While high-input program participants in our sample had significantly higher plant densities than plots of improved management only or control groups, high-input densities were still well below recommended levels: 30,808 plants/ha compared to the recommended level of 50,000 plants/ha. Further investigation is required to determine the factors underlying these discrepancies and for the large variation in density across plots.

Seed and fertilizer recommendations in the high-input package were standard across the three agroecological regions we examined, but the analysis suggests that differences between the three agroecological regions are significant. Fine-tuning seed, fertilizer and crop management recommendations could improve yields, given the differences in soil types, rainfall, altitude and other agroecological characteristics between the three regions. Farmers also noted yield losses due to locally severe problems with termites and rats, wind damage in higher-elevation areas and drought. More region-specific adaptive research is needed to identify specific solutions, e.g., recommendations on pesticide use and ways to increase its availability at the local level, and on specific varieties that could better withstand wind and drought conditions.

The lack of clarity regarding whether input credit would have to be repaid, combined with the late delivery of inputs in two of the three regions, may have compromised the technical performance of the improved seed and fertilizer, and reduced farmer incentives to manage their plots – especially weeding – as well as they might have.

Key Findings: Financial Analysis

The yield results indicate that farmers can significantly increase maize yields through the application of the recommended improved seed and fertilizer package, if inputs are delivered on time and crop management recommendations are followed. The results of the financial analysis are more sobering. Under the conditions faced by smallholder farmers in 1997/98 (including uncertainty about weather conditions, the timing of input delivery and commodity prices), the analysis indicates that in most scenarios (sales in September, shortly after harvest, or in November, or January) the yield gains did not compensate for the high cost of the inputs, if net income/ha is used as the measure of profitability. Farmers achieved higher returns (net income/ha) when they used only improved management techniques without purchased seed or fertilizer. Only in Region 8 (Monapo/Meconta), where inputs were delivered on time and weather conditions were good, did the profitability of the high-input package exceed that of improved management alone, and then only if farmers waited until January to sell maize (benefitting from a price rise of 100% between September 1997 and January 1998).

The results of the financial analysis also suggest that all farmers – regardless of the technology package used – can potentially benefit from gains to storage and later sale of maize, especially when insecticide is used to reduce grain losses to storage pests. Gains from storage are not assured, however. In 1997/98 seasonal price rises were impressive, but in 1998/99 because of increased production in Mozambique and the southern Africa region generally prices have been much flatter.

The main finding from the financial analysis is that the use of improved technology on maize can result in increased yields and profitability, but the level of risk and uncertainty surrounding use of improved maize technology, and the cost of supplying improved seed and fertilizer, are very high. In 1997/98 the yield increases generated through the use of the technology package generally did not compensate for the high cost of the inputs given prevailing output prices.

Conclusions

The results of this analysis suggest the need for policy and program actions, and further research, to reduce (1) the risks and uncertainty of input use at the farm level, and (2) the cost of input supply, to allow Mozambican smallholders to benefit from technological improvements that can potentially increase yields, food security and incomes. Possible actions and research include:

Reducing production risk by fine-tuning agronomic recommendations. There were significant differences in yield response between the three agroecological regions studied. Because a large part of the differences may be attributable to variations in altitude, rainfall, and soils, this suggests the need for fine-tuning the current blanket agronomic recommendations. Institutional incentives are required to motivate researchers and extensionists to modify technology recommendations for specific areas by synthesizing the results from on-station and on-farm trials, including INIA's national geographically-referenced database on soil quality and response to fertilizer.

Focusing more adaptive research and extension effort on solving problems that seriously affect maize yield. Our analysis indicates that plant density -- in conjunction with improved seed and fertilizer use-- is the most important determinant of maize yield. Our results revealed very high levels of variation in plant density among high-input farmers, 26,000-33,000 plants per hectare, compared to the recommended level of 50,000 plants per hectare. Closer extension supervision at planting time may be required, but adaptive research is also needed to address other problems identified by farmers (e.g., termites, rats, early season mini-droughts).

Adjusting agronomic recommendations according to farmers' ability to bear risk. Recommendations, particularly for expensive inputs such as commercial fertilizer, may also need to be adjusted on the basis of farmers' capacity to bear risk. For example, farmers who have more than one commercial crop, e.g., cotton and maize, may have a higher risk threshold. In the event of a poor return on one crop(e.g., maize), maize input loans can be paid off with returns from cotton. More research needs to be carried out to understand how farmers perceive risks and the attractiveness of alternative investments within the farming system, but preliminary results suggest the need for recommendations geared not only to agroecological differences but to variations in farmers' ability to spread risk among different crops in the farming system, or among different on- and off-farm enterprises.

Improving research and extension on the costs, returns and risks of alternative technologies in a cropping systems context. Through the efforts of the Cooperative League of the USA (CLUSA) and other NGOs, farmers in Nampula Province are becoming more aware of the potential costs and returns from alternative commercial crops, e.g., cotton, maize, sunflower, sesame, pigeon pea-- and the importance of analyzing these during pre-season planning. Researchers and extensionists can contribute significantly to this discussion, by (1) collecting data on labor inputs and carrying out financial analysis of trials (especially on-farm trials) of new technology and crop management techniques; (2) making information on yield and profitability available to farmers in an easy-to-understand extension bulletin format; (3) DNER, DAP and SIMA (Market Information System) collaboration to assess and extend information about the price risk associated with alternative commodities; and (4) improving research and extension on alternative crops and technologies in a cropping systems context.

Reducing the cost of input supply. Our analysis showed that the cost of improved seed and fertilizer represented 68-80% of production costs (exclusive of family labor) for sample farmers. Reducing costs at strategic points in the input sector will clearly improve the farm-level profitability of improved technology. The research activity described in this paper did not focus on the impact of government and donor policies and programs on input supply, but these are discussed at length in a recent DAP study on constraints and strategies for the development of the Mozambican inputs sector. Key recommendations of that paper include (a) investments to reduce transport costs, including road, rail and shipping infrastructure, and incentives to the private sector to expand and maintain rural transport fleets; (b) government withdrawal from management of the KRII program for supply of fertilizer, pesticides and machinery; (c) reduction of policy barriers to regional trade in inputs by the private sector, and research to explore the possibility of reducing shipping and transport costs through bulk ordering of fertilizer with partners in neighboring countries; (d) expansion of programs to train input dealers in rural areas; and (e) programs to supply improved seed varieties to remote, less commercially developed areas of Mozambique.

Farmer associations are increasingly active in Nampula Province and present one of the most promising avenues for lowering input and output marketing costs. Farmer associations can potentially lower the private sector costs of input supply and credit recovery, and increase extension effectiveness, by (a) aggregating input demand from scattered rural villages; (b) organizing local delivery to member villages after inputs are delivered to a central location; (c) organizing extension assistance on a group basis; and (d) providing group guarantees for input loans.

TABLE OF CONTENTS

LIST OF TABLES

FIGURE

APPENDIX

Comparing Yields and Profitability in MADER's High- and Low-Input Maize Programs: 1997/98 Survey Results and Analysis

1. INTRODUCTION

Mozambique, one of the poorest countries in the world, must increase agricultural productivity to feed its growing population and spur economic recovery following years of civil war. Maize is Mozambique's most important food crop. Maize is planted on over one-third of Mozambique's total cultivated area, supplying 25% of all calories and 61% of calories from cereal (DEA 1998, FAOSTAT 1999). Intensification is one way to increase productivity, but the use of technologies such as improved seed and fertilizer is extremely limited.

The Department of Rural Extension (DNER) in the Ministry of Agriculture and Rural Development (MADER) operates several programs to stimulate maize production through the use of improved technologies in Mozambique's high-potential regions, including (1) DNER's basic approach of extending improved planting and weeding practices (with local or improved seed, but without fertilizer) to participating farmers; and (2) the DNER/Sasakawa-Global 2000 Program (DNER/SG) in which participating farmers receive fertilizer and improved seeds on credit for use on a half hectare of their land.

Until recently no formal analysis had been carried out to assess the yield performance and profitability of the improved technology packages. In 1996/97 the Department of Policy Analysis (DAP) in MADER's Directorate of Economics began collaborating with DNER on a three-year study of yields and profitability in alternative maize intensification programs. During the first season (1996/97) we analyzed the farm-level impacts of the DNER/SG Program, interviewing 223 DNER/SG participants in Manica and Nampula Provinces.[1] Key findings from 1996/97 included:

- Average DNER/SG maize yields (with improved inputs) were 2.3. tons/ha, much higher than the provincial averages (without improved inputs), which ranged from .4 to 1.3 tons/ha;

- Yields varied greatly even within the same agroecological zone and among farmers using the same seed variety and fertilizer rate. DNER/SG Program yields ranged from .5 to 4.9 tons/ha;

- The profitability of improved input use varied significantly depending on yield levels, the agroecological region and the timing of maize sales. During 1996/97, storing maize for several months dramatically increased farmer gains. When farmers sold immediately after harvest (June), only 36% made a profit. At the December price, 80% profited. Farmers in the bottom two yield terciles earned attractive returns only if they waited until December to sell.

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[1] The 1996/97 results are reported in Howard, Julie A, José Jaime Jeje, David Tschirley, Paul Strasberg, Eric W. Crawford and Michael T. Weber. 1998. *What Makes Agricultural Intensification Profitable for Mozambican Smallholders?* NDAE Working Papers No. 31 and 32 (Volumes 1 and 2). Maputo: MADER

This paper summarizes the results from data collected and analyzed during the study's second year. The 1997/98 analysis is based on a stratified sample of 210 smallholder maize farmers in Nampula Province. In contrast to the 1996/97 research, when the sample was composed entirely of farmers using the DNER/SG high-input package (improved seed, fertilizer, improved practices), the 1997/98 sample strata represent three different sets of production practices: (1) the DNER/SG high-input, improved management package; (2) an improved management only program implemented by the extension service (improved practices, local seed, no fertilizer); and (3) a control group of farmers who did not participate in any formal program. These farmer groups will be referred to as (1) high-input; (2) improved management only; and (3) control types.

1.1. Objectives

Our specific research objectives were to:

1. Describe (a) the characteristics of high-input, improved management only and control group participants; (b) input use patterns; and (c) yield response by group;

2. Analyze the relative contribution to yield of (a) different types of technologies, (b) environmental factors, and (c) management practices; and

3. Assess the profitability of the three different plot types at the farm level.

1.2. Methods

1.2.1. Sample Selection

Agroecological regions. Sample farmers were selected from three different agroecological regions of Nampula Province: Ribaue District (Region 7), Monapo and Meconta Districts (Region 8), and Malema District (Region 10). All three regions are considered to have good to excellent conditions for maize production. Figure 1 shows the location of survey sites and Table 1 describes the major agroecological characteristics of each region.

Technology types. The sample was drawn from three distinct groups of farmers within each agroecological region. High-input farmers participated in a special DNER/SG program that provided 15 kg of improved open-pollinated seed, 50 kg of 12-24-12 and 50 kg of urea on credit for use on ½ hectare of the farmer's own land. The credit was to be repaid at harvest with a flat interest rate of 15% (equivalent to an annual rate of 22.5%). High-input farmers received more intensive extension assistance than farmers in the other two groups. Farmers were directed to plant in rows soon after the onset of the rainy season (late November to late December) and to apply one spoonful of 12-24-12 per hill at planting time. The recommended hill spacing was 90 cm x 40 cm, with two seeds per hole, resulting in a target plant density of 50,000 plants/ha. Urea was to be applied as a side dressing when plants were knee high. Farmers were asked to weed at least twice.

In 1997/98, sample farmers in the improved management only group used local seed and followed management practices specified during regular meetings with the individual extension agent, but did not use fertilizer. Members of the control group used local seed and traditional practices, but no fertilizer.

Sampling procedure. Sample farmers were selected as follows. First, a complete listing of extension agents working in the three agroecological regions was made. To select farmers for the high-input sample, each extension agent was asked to draw up a list of all farmers participating in the high-input program under his/her supervision. Each agent then randomly selected 2 farmers for inclusion in the sample.

A two-stage process was used to select farmers for the improved management only sample. Each extension agent first compiled a list of all farmer groups assisted by him/her. Two of these groups were randomly selected. The agent then drew up an alphabetical list of all farmers growing maize in a sole stand who regularly participated in these groups. One farmer per group was randomly selected for the sample.

To select the control group, extension agents were asked to list all farmers growing sole-cropped maize within a 1 kilometer radius of the first high-input participant. One of these control farmers was selected for the sample, and the process was repeated for the second high-input participant. The procedure was repeated for the improved management only participants -- all farmers within 1 kilometer were listed and one was randomly selected for inclusion in the control group.

The objective was to draw a sample of roughly equal size for each of the three agroecological regions, with each farmer group equally represented. Table 2 summarizes the sample size by region and technology type. The sample was composed of 82 farmers in Ribaue (Region 7) and 96 farmers in Monapo/Meconta (Region 8). The sample for Malema (Region 10) was much smaller -- 30 farmers -- because there were very few high-input participants in this region. All high-input farmers in Malema were chosen for inclusion in the sample.

Figure 1. Survey Sites

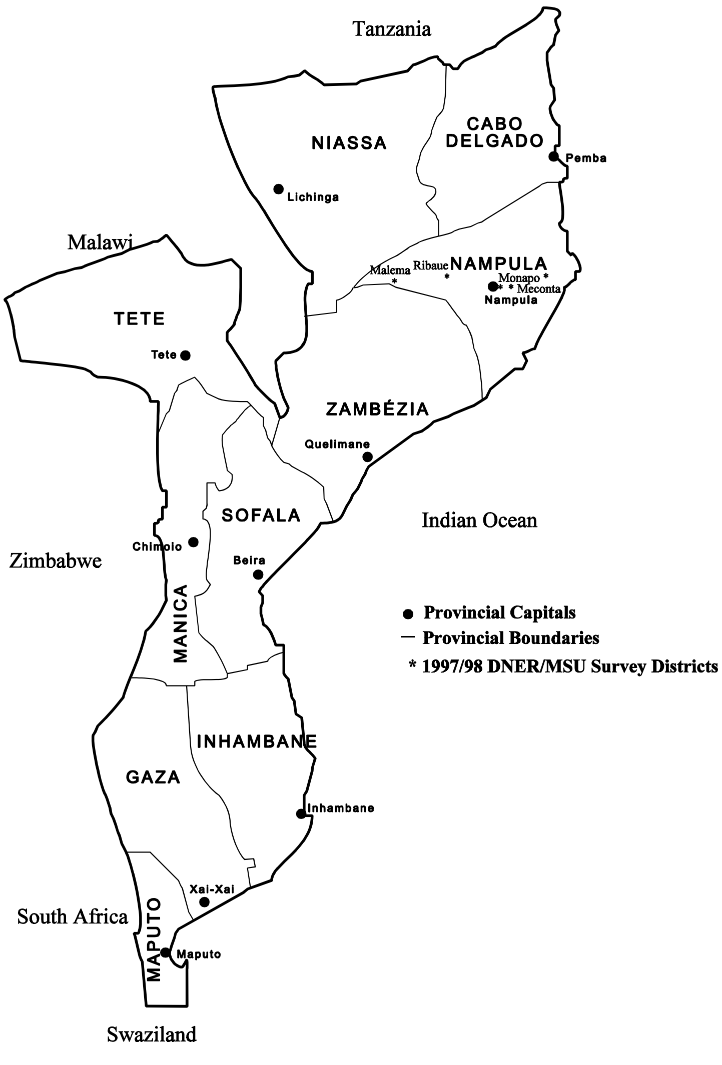

Table 1. Agroecological Characteristics and Maize Technology

Characteristic→ Region ↓	Altitude (meters above sea level)	Avg. rainfall (mm)	Avg. temp. during cropping season	Soils	Major crops
Ribaue (Region 7)	200-1,000	1,000-1,400	20-25°C	sandy to heavier clay	maize, sorghum, cassava, cowpea, groundnut, cotton
Monapo/ Meconta (Region 8)	coastal	800-1,200	>25°C	sandy, heavier soils in low-lying areas	cassava, maize
Malema (Region 10)	>1,000	>1,200	15-22.5°C	heavy	maize

Source: MAP 1996

Table 2. Sample Composition

Characteristic→ Region ↓	Total number of farmers	High-input participants	Improved management only group	Control group
Ribaue (Region 7)	82	34	27	21
Monapo/Meconta (Region 8)	96	32	34	30
Malema (Region 10)	30	13	10	7
Total	208[2]	79	71	58

Source: Survey data

1.2.2. Questionnaire Design and Data Collection

Primary data collection was carried out in two rounds between May and August 1998. Forty-two area extension agents served as enumerators, working under the supervision of DAP/DNER staff. Training and questionnaire pre-testing were carried out during May and early June. Primary data collection began in mid-June and continued until August. Additional data on transport and other subsector costs were collected from November 1998 to March 1999 through informal interviews with private sector importers, transporters, wholesalers and retailers, and a review of secondary documents.

[2]Two households were dropped from the original sample (210 households) because of missing yield data.

Yield estimation. During the first round of data collection, enumerators marked, harvested and weighed the grain from 3 randomly-selected 49 square meter areas per field for yield estimation.

Collection of area, agronomic, demographic and input use data. During the second round of data collection, enumerators measured the area of the sample plot; gathered information about the soil characteristics and history of the sample plot; collected demographic data on the household; compiled general information for the whole farm on area/input use for major crops and changes in livestock holdings over the past five years; and collected specific information for the high-input, improved management only or control plot regarding (a) dates of major field activities and receipt of inputs obtained on credit; (b) household and non-household labor inputs and costs; (c) amounts used and costs of other inputs (including animals, tractor, fertilizer, seed); (d) farmer assessment of the impact of weather events and pests on production; and (e) farmer perception of the importance of purchased inputs.

Analytical methods. We used several complementary analytical methods to address the research objectives. Econometric yield models were estimated to quantify the effects of key inputs and field practices on productivity, and financial budgets were constructed to assess the farm-level profitability of the maize technology.

1.3. Organization of the Paper

In the following section we summarize key socioeconomic indicators for the sample farmers and compare these characteristics to average values for Nampula Province and Mozambique. In section 3 we present maize yield results and discuss the key factors affecting yields. Results of the farm-level profitability analysis are presented in section 4. The paper concludes (section 5) with a summary of the main findings and a discussion of implications for policies and future programs aimed at increasing the use of improved technologies.

2. CHARACTERISTICS OF SAMPLE FARMERS AND TYPICAL AGRICULTURAL HOUSEHOLDS IN NAMPULA PROVINCE

Extension programs sometimes introduce new technologies to richer, more highly educated farmers first, then extend the technologies to poorer farmers after the yield advantage and profitability of the package have been demonstrated. It is important to know whether DNER/SG high-input program participants are "better-off" farmers. If they are, the survey findings may have limited applicability beyond this higher income group. Extension techniques that are successful with this group may also need to be modified for poorer farmers. To assess whether our high-input group farmers are "better off" than average farmers, we compared key characteristics of farmers in the high-input, improved management only and control groups with similar indicators for Nampula Province farmers from the 1996 National Survey of Smallholder Agriculture (Table 3).

There were few significant resource differences between farmers in the three groups. The only statistically significant difference was years of education. High-input users were more highly educated than other farmers. Other resource differences -- land, labor, and wealth as reflected by livestock holdings -- were not significant. In general farmers in the 1997/98 sample were more likely to use fertilizer than Nampula farmers surveyed in 1995, perhaps reflecting the expansion of commercial agricultural crops in recent years. Farmers with average resources, even those not in a formal program, are experimenting with improved inputs. This bodes well for the future extension of high-input technologies to areas with similar agroecological conditions.

Table 3. Selected Characteristics of Participant Households Versus the Broader Population of Agricultural Households

	DNER/SG High-Input Program	Improved Management Only	Control Group	Nampula Prov./ Moz.
Average farm area (ha/household)	2.5[a]	2.5[a]	2.1[a]	2.1[b]
Mean household size (persons/household)	5.6[c]	5.1[c]	4.6[c]	4.7[d]
Average hectares cultivated per capita[e]	.5	.5	.5	.45
Mean years of school completed[f]	3.6[g]	2.4[g]	2.8[g]	[i]
Mean livestock units per household[h]	2.4	2.8	2.0	
% using chemical fertilizer in 97/98[j]	100.0	9.3	5.4	0.3[k]
% using improved maize seed in 97/98	100.0	12.7[l]	19.0[l]	<20[m]

Notes:
[a] Source: Survey data. Median estimates based on farmers' own estimates of total farm area. Does not include land planted with fruit-bearing trees. Differences between program groups were not significant.
[b] Source: DEA 1998. [c] Source: Survey data. Differences between program types were not significant. [d] Source: DEA 1998.
[e] Values are medians for the 3 program groups. Ratios are calculated at the household level first, then all observations are ranked to find the median. Source of Nampula Province estimates: DEA 1998.
[f]Source: Survey data. Differences between the three groups were significant at the .007 level.
[g]Source: Survey data.
[h]Calculated using the following weights: cattle=1, sheep/goats=.5, horses/mules=.7, pigs=.5, fowl=.15, rabbits=.1. Differences between program groups were not significant.
[i]Not available. [j]Source: Survey data. [k]Source: DEA 1998.
[l]Source: Survey data. For low-input and non-program participants, may include recycled improved varieties.
[m]Source: Dominguez and Chidiamassamba 1997

3. YIELD RESULTS AND DETERMINANTS

In the following sections we present and analyze the maize yield results obtained by high-input, improved management only and control group farmers in our sample. In section 3.1, we examine maize yield levels and variability. In sections 3.2 and 3.3., we analyze the key factors affecting yields and quantify their relative impacts.

3.1 Yield Results

Average yields in the 1997/98 season ranged from 1.4 tons/ha for control group members to 1.7 tons/ha for improved management only farmers and 2.0 tons/ha for high-input farmers (Table 4). Yields for all groups exceeded average yields for Nampula Province in previous years by a wide margin. Provincial averages were 0.8 ton/ha in 1994/95, 0.9 ton/ha in 1995/96 and 1.0 ton/ha in 1996/97 (Howard et al. 1998).

Although average high-input yields exceeded improved management only and control group yields across the sample, when the results are disaggregated by region they reveal that high-input yields are significantly higher than improved management yields only in Monapo/Meconta Districts (Region 8). Average high-input yields in Region 8 were 2.7 tons/ha, compared to 2.0 tons/ha for improved management only farmers and 1.8 tons/ha for control group members. Differences between groups in Regions 7 and 10 were not statistically significant (Table 5).

Yield variability as measured by the coefficient of variation[3] was high across the sample, but instability -- thus risk -- was greater for high-input farmers than in the other groups. In the overall sample, average high-input yields deviated from the mean by 57%, compared to 45% for improved management only farmers and 48% for control group participants (Table 4). When results are disaggregated by region, yield variability is again greater for high-input farmers compared to other groups in Regions 7 and 8 (Table 5), but in Region 10 it is higher for control and improved management only groups. This result may be influenced by the relatively small sample size in Region 10 compared to the other regions.

3.2. Econometric Analysis of Maize Yield Determinants

The objective of the analysis in this section is to identify the key factors influencing maize yields and to quantify the relative impact of these factors. To accomplish this we constructed yield models at cross-regional and regional levels. In section 3.2.1.we explain how we dealt with the disaggregation of technology effects in our analysis. Sections 3.2.2 and 3.2.3. summarize and interpret the main results from the cross-regional and regional yield models.

[3] The coefficient of variation expresses the standard deviation as a percentage of the mean.

Table 4. Average Maize Yields by Technology Type

Types of Maize Technology	Number of plots using a given technology	Average yields (kg/ha) (c.v. in parentheses)	Average fertilizer applied (kg/ha)	
			DAP	Urea
(1) **High Input** Improved seed, fertilizer and practices (coefficient of variation)	79	1980 (57.3)	100	100
(2) **Improved Management Only** Local seed, no fertilizer, improved practices (c.v.)	71	1720 (45.0)	0	0
(3) **Control Group** Local seed, no fertilizer, traditional practices (c.v.)	58	1447 (48.1)	0	0

Source: Survey data

Table 5. Disaggregation of Maize Technology Types by Agroecological Region

Techno-logy type	Region 7 (Ribaue)			Region 8 (Monapo/Meconta)			Region 10 (Meconta)		
	Number of plots	Average yield/ha*	Average plant density/ ha	Number of plots	Average yield/ha **	Average plant density/ ha	Number of plots	Average yield/ha ***	Average plant density/ ha
(1) High Input (c.v.)	34	1343[a] (53.2)	29,632 (40.5)	32	2701[a] (47.1)	32,847 (36.6)	13	1872[a] (25.7)	26,211 (32.5)
(2) Imp. Manage-ment Only (c.v.)	27	1322[b] (43.9)	16,435 (38.0)	34	1969[b] (34.8)	19,117 (33.9)	10	1950[b] (56.0)	18,442 (34.8)
(3) Control (c.v.)	21	1086[c] (34.8)	13,874 (26.2)	30	1747[c] (38.6)	17,943 (45.5)	7	1247[c] (79.1)	16,900 (49.8)

Source: Survey data
Notes:
* a=b=c (no statistically significant difference between groups)
** a>b>c (yield for each group is statistically different from other groups)
*** a=b=c (unable to show statistically significant difference due to small sample size)

3.2.1. Analysis by Technology Type

Under experimental conditions it would be possible to include the technology variables -- seed, 12-24-12 and urea -- as separate variables in the regression equations to assess the relative impact of each input on yield. This proved impossible because of the lack of variability in the use of these factors among farmers in our sample. Farmers who used improved seed used exactly the same variety, and those who used improved seed also used exactly the same quantities of 12-24-12 and urea. Consequently in our analysis input levels are represented by technology types: technology type 1 represents high-input farmers who used improved seed and fertilizer; technology type 2 represents farmers who used improved management practices only, and technology type 3 is the control group -- farmers who used traditional technologies (no fertilizer or improved seed) and received no extension assistance.

In addition to technology type, the other factors examined in our yield models fell into two broad categories: (1) exogenous factors that farmers respond to but cannot completely control such as rainfall, soil type, disease and pest attacks; and (2) endogenous factors linked to management practices such as plant density, the timing of critical operations and amount of labor used.

3.2.2. Results from the Cross-Region Yield Model

Table 5 shows average yield and plant density for the three technology types by region. Table 6 summarizes other key results from the cross-region yield model.[4] The model explains half of the variation in yield (adj. R^2=.49). Because logged variables are included in the equation, we report the standardized coefficients, indicating the relative contribution of each factor to overall yield.

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[4]Our models exhibited severe multicollinearity among the major explanatory variables, especially between plant density and technology type. Higher plant density was a key extension message for high-input farmers; thus plant density was highly correlated with participation in the high-input program. The relationship is readily apparent in Table 5. Including plant density and technology type as explanatory variables in the same equation invariably resulted in a very unstable model, while excluding one or the other key variable resulted in a model with little explanatory power.

The approach we used to address this problem (suggested by Prof. Jim Oehmke) was to regress plant density on the other explanatory variables in the equation, then substitute the residuals from this equation back into the yield equation instead of using the plant density variable directly. This approach permits the indirect effect of other explanatory variables that are influencing yield through an impact on plant density to be captured (along with the direct effects) by the coefficients for each variable in the yield equation, rather than being lumped together in the coefficient for plant density. The variable created using the residuals from the plant density equation represents only that part of the variability in plant density that is not explained by the other variables in the equation, i.e., the direct effect of plant density on yield.

It is important to note that with this type of model it is generally not possible to draw conclusions about the relative contribution of the direct and indirect effects of different variables. However, in this case we suspect that the indirect effect of high-input technology (improved seed, fertilizer, improved practices) is strong because in the cross-region model technology type 1 (TECH1) was the only significant variable in the plant density equation. The results of all cross-region and region-specific plant density equations are presented in Appendix 1.

Technology and program implementation. The factors that had the strongest impact on yield were closely related to the technology package and program implementation. The most important factor was location in agroecological region 8. The regional dummy variables reflect both agroecological impacts (e.g., differences in altitude, rainfall, soil-- discussed below), and other factors that varied across regions. The Region 8 variable probably reflects the positive impact of on-time input delivery on maize yields in that region. In Regions 7 and 10 late input delivery led to planting delays of 2-5 weeks for high-input farmers compared to farmers in the other groups (Table 7).

Yields in Regions 8 and 10 were significantly higher than in Region 7. Region 7 yields were also the lowest among all regions in our 1996/97 survey. A possible explanation is poorer soil fertility compared to the other regions. Soils in Region 7 are predominantly acid Acrisols, while more fertile Luvisols and Lixisols are common in Regions 8 and 10 (Geurts 1997). Relatively more Region 7 sample farmers also reported having poor soils.[5] In general, agroecological differences between Region 7, 8 and 10 (yield differences between Regions 8 and 10 were also statistically significant) suggest the importance of fine-tuning seed, fertilizer and crop management recommendations to help farmers increase yields and profits.

Another key factor influencing yields was plant density. The extension recommendation for high-input plots was 50,000 plants per hectare. Extension agents also recommended row planting and increased plant densities to some improved management only groups. Table 5 indicates that high-input plant density fell well short of the target, but it was significantly higher (26,211-32,847 plants/ha) than that of improved management only (16,435-19,117 plants/ha), whose densities were statistically greater than those of control groups (13,874-17,943 plants/ha).

The model results also indicate that the use of improved seed and fertilizer (TECH1) clearly had a large and positive influence on yield. The standardized coefficient for TECH1 (.343) is almost as large as for plant density (.379). As noted previously, the TECH1 and plant density variables are highly correlated and the indirect and direct effects of TECH1 on plant density and on yield are difficult to separate in this model. It is not possible to conclude that either plant density or the improved seed/fertilizer technology had the more important impact on yield. This has practical significance, since separate recommendations (a) to greatly increase plant density in the absence of soil fertility supplements or (b) use improved seed and fertilizer without a corresponding increase in plant density are unlikely to result in sustainable yield increases.[6]

The impact of improved practices and additional extension assistance provided to farmers in the improved management only group (TECH2) also had a positive and significant effect on maize yields

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[5]Twelve per cent of Region 7 sample farmers classified their plots as "low" fertility (vs. average or high fertility), compared to 5 and 7 per cent of farmers in Regions 8 and 10.

[6]Recent findings of a CERES maize simulation model for Ethiopia showed that there is little payoff to increasing plant density when no fertilizer is applied. Also, in order to take advantage of the increased yield potential of improved varieties and fertilizer it is necessary to increase plant density significantly (Schulthess and Ward 1999).

Table 6. Cross-Region Regression Analysis of Factors Affecting Maize Yields

	All Zones (Adj. R^2=.49, F=18.577)[a]				
Variables	Coef.	SE Coef.	Stdized Coeff.	T	Sig. T
Constant	6.526	.144		45.389	.000
REGION 8 1=Region 8 0=otherwise	.452	.065	.430	6.953	.000
PLANT DENSITY Residual from plant density equation	.508	.070	.379	7.209	.000
TECH1 1=fertilizer+improved seed 0=otherwise	.367	.074	.343	4.937	.000
OTHERDAM 1=reported significant damage from termites, wind,drought,flood,or rats 0=no or little damage	-.284	.062	-.255	-4.566	.000
SOILFERT 1=high or medium fertility 0=low	.378	.106	.197	3.55	.000
TECH2 1=improved practice/ extension assistance 0=otherwise	.197	.072	.179	2.746	.007
REGION 10 1=Region 10 0=otherwise	.219	.086	.154	2.55	.012
WKPLANT week of planting; 1=4th week October 2=1st week Nov.,etc.	.0192	.011	.098	1.712	.089
EDUC grade level completed	-.0192	.013	-.087	-1.529	.128
PLTLAHA number of adult-equivalent labor days used for planting	-.0028	.003	.055	.989	.324

Source: Survey data

[a] 17 households of the total sample of 208 were excluded from the cross-regional and regional analyses because of extreme values in key variables that suggested data errors.

Table 7. Input Receipt and Planting Dates

Group→ Region↓		**High-input**	**Low-input**	**Non-program participants**
Region 7	Planting week	3rd December	1st December	1st December
	Receipt of improved seed/ fertilizer	3rd December		
Region 8	Planting week	3rd December	2nd December	2nd December
	Receipt of improved seed/ fertilizer	1st - 2nd December		
Region 10	Planting week	1st January	1st December	3rd November
	Receipt of improved seed/ fertilizer	4th December		

in the sample. However, the smaller size of the standardized coefficient for TECH2 (.179) relative to TECH1 (.343) indicates that the impact of the extension assistance alone was far less important than the extension aid combined with improved seed and fertilizer provided to the high-input group.

Crop damage factors. Farmers were asked whether their maize plots had suffered extensive damage (affecting >10% of production) from a variety of causes, namely termites, high winds, drought, flooding of fields or rats (damage from disease, insects or weeds was recorded in separate variables which were not significant in this model). The model results indicate that these problems had strong and significant negative impacts on yields. Farmers clearly have little control over some of these factors, e.g., wind, drought, but pesticides to control termites and rats are available in Mozambique. Individual damage factors were isolated in some of the region-specific results presented in Section 3.2.3.

Soil fertility. Farmers were asked to assess whether their maize plots had low, medium or high levels of fertility. The model results suggest that farmers were good judges of their plots. Yields were significantly higher for plots which were reported to have medium or high fertility than plots with low fertility.

Other factors. Other variables included in the yield equation were not significant at the standard .05 cutoff level. Planting week was positively related to yield and was significant at the .09 level. This result indicates that sample farmers who waited to plant had higher yield results than those who planted earlier. This is contrary to expectation since the usual recommendation is to plant soon after the first substantial rainfall. Further analysis is needed, but the influence of technology type may be confounding here. As noted earlier, farmers in the high-input group who used improved seed and fertilizer got their inputs late in Regions 7 and 10 and planted 2-5 weeks later than their counterparts in improved management only and control groups. In spite of these delays high-input farmers got higher yields than their counterparts in two of the three regions (but probably not as high as they could have had inputs arrived on time). Where inputs did arrive on time and high-input farmers planted at roughly the same time as other groups (Region 8) the yield differences were much more dramatic.

The level of education was negatively correlated with maize yields but significant only at the .13 level. This again is an unexpected sign but consistent across the individual regions (see Section 3.2.3.). One implication is that technology programs aimed at potentially fast adopters should not necessarily use education level as a screening variable. The amount of labor used for planting was positively correlated with yield, but it is a weak relationship (significance level=.32), possibly a result of problems with the quality of labor data collected through the one-time end of season recall approach.

3.2.3. Results from the Regional Yield Models

In addition to the cross-region model reviewed above, we also constructed separate yield models for Regions 7, 8 and 10 in order to better understand the factors affecting yield in each agroecological zone. Tables 8, 9 and 10 present the results of these yield models. Results from the plant density models for each region can be found in Appendix 1.

<u>Region 7</u>. As in the cross-region model, the most important variables in the Region 7 model are technology-related. The use of fertilizer and improved seed (TECH1) and higher plant densities were strongly correlated with higher yields (Table 8). Improved management practices alone (TECH2) also contributed to yield but had a much weaker effect than improved management combined with seed and fertilizer (sig.=0.1). Level of education was significant and negatively related to yield. Other key variables were related to the environment. Drought had a significant, negative impact on yield. Seventeen per cent of Region 7 farmers said they suffered significant production losses as a result of drought. Farmers who reported high or medium soil fertility (88%) had significantly higher yields than those with less fertile maize plots. Termite damage negatively affected yields (significant at the .08 level); about one-fifth of Region 7 farmers said their production was badly damaged by termites. The amount of planting labor used was negatively related to yields, but the relationship was not significant (.34).

<u>Region 8</u>. The yield models for Regions 7 and 8 are very similar, although the Region 8 model has greater explanatory power, accounting for 50% of yield variation compared to 30% in Region 7 (Table 9). High plant density and use of improved fertilizer and seed inputs (TECH1) were again by far the most important factors explaining higher yields. Improved management alone (TECH2) was also positively correlated with yield, but the relationship was much weaker (sig. = .14). Maize yields

from plots with medium or high soil fertility were significantly higher than on less fertile plots. Termite damage (reported in 18% of plots) had a negative impact on yield (sig.= .099). Education levels were again negatively correlated with yields (sig.=.1). Good rainfall distribution (reported by 14% of farmers, with the remainder reporting average or poor distribution) was positively related to yields, but the level of significance was low (.16).

Region 10. The Region 10 yield model explained 60% of the variation in yield (Table 10). Unlike the other models, improved seed and fertilizer use (TECH1) were not significant determinants of yield in this model. High-input yields in this region (1.9 tons/ha) were also lower than improved management only yields (2.0 tons/ha), although the differences were not significant. One hypothesis is that the poor performance of seed and fertilizer technology in this region is related to the serious delay in input delivery and planting. Region 10 villages participating in the high-input program are remote, located in difficult terrain and served by few paved roads. High-input farmers received improved seed and fertilizer during the last week of December and planted the first week of January, a full 4-6 weeks after improved management and control group farmers in the same areas planted (Table 7). Region 7 farmers also received inputs late, but planting by high-input farmers was delayed by just two weeks.

Environmental factors were the key determinants of yield in Region 10. Plots where production was damaged significantly by termites, wind, drought, or flooding or rats yielded significantly less than plots with little damage. Flooding and wind were the major problems reported by farmers; 17% reported significant damage from wind and 13% from flooding. Maize planted in red soils yielded significantly more than maize planted in black or white soils. Forty percent of Region 10 farmers said that they planted maize in red soils.

Program-related variables were also statistically significant determinants of yield, but were less important than environmental factors. Higher plant densities were again associated with increased yields, as was extension assistance for improved management only farmers (sig.= .08). Three-quarters of Region 10 farmers complained that rainfall distribution in 1997/98 was poor. The yield model showed a positive correlation between yield and poor distribution but the relationship was significant only at the .11 level.

3.3. Summary

Several points emerge from the preceding analysis. First, average yields for sample farmers in all groups -- high-input, improved management only and control -- exceeded average yields at the provincial level reported for previous years by a wide margin. Our analysis of socioeconomic characteristics in the previous section indicated that sample farmers are not significantly better off in terms of resources than average farmers in Nampula Province. The relatively high sample yields for farmers using no improved inputs (compared to provincial averages) suggest that the sites included may have relatively better cropping conditions than other areas in the province. Therefore it will be important to use caution in generalizing from these findings to areas where agroecological conditions are less favorable.

Second, an examination of average yields by region and technology type showed that yields from high-input (improved seed, fertilizer, extension assistance) plots were significantly higher than yields from improved management plots (extension assistance only) only in one region -- Region 8. Despite this apparent evidence of poor average performance from high-input technology, our econometric analysis of yield determinants revealed a very strong and positive relationship between higher yields and the use of improved seed and fertilizer together with increased plant density. The results suggest that high-input maize technology holds considerable potential for increasing yields, but the performance of the improved input package may have been compromised by poor program implementation in 1997/98. In two of three regions, improved seed and fertilizer were delivered late. Planting was subsequently delayed by 2-5 weeks.

The results also show that use of high-input technology is currently riskier (i.e., yields are less stable) than low-input or traditional methods. This is an especially important consideration if high-input technology is extended to farmers in more marginal agroecological areas or with fewer household resources for whom a yield loss in one season could be catastrophic.

Finally, the results of the yield analysis suggest several avenues for improving the performance of high-input technology in Nampula Province. A key issue is how to assure that farmers receive inputs on time so that the full benefits of the technology can be captured. The lack of a private rural input supply network and poor transportation infrastructure are major problems for MADR, SG2000 and other partners. These obstacles necessitate the virtual hand-delivery of inputs to farmers at great difficulty and cost. Options for accelerating the development of the input supply network will be discussed in Section 5.

The analysis clearly shows that increasing plant density is critical to improving yields of high-input maize. While high-input program participants in our sample had significantly higher plant densities than plots of improved management only or control groups, high-input densities were still well below recommended levels (30,808 plants/ha compared to the recommended level of 50,000 plants/ha). Further investigation is required to determine the cause for the differences and for the large variation in density across plots, e.g., unclear extension messages about seedbed preparation and planting methods, farmer lack of confidence in the recommendations for other reasons, or other disease and insect problems. Some of the variability in yields and plant density may have resulted from the misapplication of seed and fertilizer provided by the MAP/SG program. We heard anecdotal reports in the field, but have no hard evidence that sample farmers held back inputs or used them (in the case of fertilizer) on other crops. Because extension agents (who were supervising the high-input program) served as our survey enumerators it is unlikely that farmers would openly report such discrepancies. In general, closer supervision by extension agents is needed to ensure that program inputs are correctly applied and other recommendations are understood and followed.

Seed and fertilizer recommendations in the high-input package were standard across the three agroecological regions we examined, but our analysis suggests that differences between the three agroecological regions – soil types, rainfall, altitude and other agroecological characteristics-- contributed to significant differences in yield performance. Fine-tuning of seed and fertilizer recommendations could help improve yields. Farmer responses also suggest the severity of local problems with termites and rats, wind damage in higher-elevation areas and drought. More region-specific adaptive research is needed to identify specific solutions, e.g., recommendations on pesticide use and ways to increase its availability at the local level, and on specific varieties that could better withstand wind and drought conditions.

Table 8. Regression Analysis of Factors Affecting Maize Yields -- Region 7

	Region 7 (Adj. R^2=.3, F=4.956)				
Variables	Coef.	SE Coef.	Stdized Coeff.	T	Sig. T
Constant	6.879	.159		43.260	.000
TECH1 1=fertilizer+improved seed 0=otherwise	.331	.108	.376	3.075	.003
PLANT DENSITY Residual from plant density equation	.453	.121	.365	3.748	.000
EDUC grade level completed	-.0535	.022	-.254	-2.482	.016
DROUGHT 1=reported significant damage from drought 0=no or little damage	-.260	.132	-.226	-1.970	.053
SOILFERT 1=high or medium fertility 0=low	.294	.136	.219	2.163	.034
TERMITE 1=reported significant damage from termites 0=no or little damage	-.239	.135	-.214	-1.772	.081
TECH2 1=improved practice/ extension assistance 0=otherwise	.192	.115	.205	1.671	.100
PLTLAHA number of adult-equivalent labor days used for planting	-.0059	.006	-.099	-.968	.336

Source: Calculated from survey data

Table 9. Regression Analysis of Factors Affecting Maize Yields -- Region 8

	Region 8 (Adj. R^2=.5, F=13.02)				
Variables	Coef.	SE Coef.	Stdized Coeff.	T	Sig. T
Constant	6.988	.170		41.07	.000
PLANT DENSITY Residual from plant density equation	.655	.091	.557	7.199	.000
TECH1 1=fertilizer+improved seed 0=otherwise	.455	.088	.497	5.156	.000
SOILFERT 1=high or medium fertility 0=low	.502	.160	.246	3.133	.002
TECH2 1=improved practice/ extension assistance 0=otherwise	.125	.084	.138	1.491	.140
TERMITE 1=reported significant damage from termites 0=no or little damage	-.151	.090	-.133	-1.673	.099
EDUC grade level completed	-.026	.016	-.133	-1.661	.101
RAINGD 1=farmer reported good rainfall distribution in current season 0=average or poor rainfall distribution	.144	.101	.116	1.425	.158

Source: Calculated from survey data

Table 10. Regression Analysis of Factors Affecting Maize Yields -- Region 10

	Region 10 (Adj. R^2=.6, F=8.2)				
Variables	Coef.	SE Coef.	Stdized Coeff.	T	Sig. T
Constant	6.917	.206		33.630	.000
OTHERDAM 1=reported significant damage from termites, wind, drought, flood, or rats 0=no or little damage	-.617	.161	-.486	-3.840	.001
REDSOIL 1=if soil is red in color 0=otherwise	.532	.151	.436	3.515	.002
PLANT DENSITY Residual from plant density equation	.489	.182	.317	2.691	.013
TECH2 1=improved practice/ extension assistance 0=otherwise	.350	.193	.276	1.809	.083
RAINBAD 1=farmer reported poor rainfall distribution in current season 0=average or good rainfall distribution	.278	.168	.205	1.658	.111
TECH1 1=fertilizer and improved seed 0=otherwise	.158	.203	.131	.776	.446

Source: Calculated from survey data

4. FINANCIAL ANALYSIS

Section 3 presented yield results and analyzed the key factors contributing to yield differences across plots where farmers used different levels of inputs. These results demonstrated that the use of improved seed and fertilizer technology significantly increased maize yields in sample regions where agroecological conditions were favorable and farmers received inputs and planted on time. Farmers using improved technology also incur additional costs to obtain these yield increases, however. Additional costs include charges for the inputs themselves, interest, and the cost of additional labor that may be required for fertilizer application, weeding and harvest. The analysis in this section considers whether gains from sale of improved maize compensate farmers for the costs of production, i.e., it is financially profitable for farmers to use improved technology on maize?

4.1. Data and Methods Used

The study used two measures, net income per hectare and net income per labor day, to evaluate financial profitability under different price and technology scenarios. A summary of key results from the maize financial budgets is presented in Table 11. Detailed budgets by agroecological region are presented in Appendix 2. Financial results are reported by program type in Mozambican meticais (mt).[7]

Using plot-level data from the survey and additional secondary data, net income was calculated as follows: (a) gross revenue was calculated by multiplying the crop yield per hectare by the farmgate price[8]; and (b) costs of production reported by survey farmers or program administrators were then subtracted from the gross revenue to obtain net income per hectare. These costs included the cost of inputs such as seed, 12-24-12, and urea; interest costs on input loans if applicable; cash or the cash value of in-kind payments to non-family laborers working on the plot; and the depreciated value of hand tools used in crop production and the cost of sacks used to transport the commodity to market.

In financial analysis no monetary value is imputed to family labor, but net income per day of family labor is calculated by dividing the net income per hectare by the number of (family) adult equivalent days used during crop production and harvest. Net income per day of family labor can be compared to area wage rates (which approximate the opportunity cost of labor) to assess the relative attractiveness of the technology at different yield and price levels.

We calculated net income under several different price scenarios, assuming that farmers harvesting in June-July 1998 sold their crop in (a) September 1998, (b) November 1998, and (c) January 1999, to

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[7]During the 1997-98 crop and marketing season the average exchange rate was 1 USD = 12,000 meticais.

[8]September farmgate prices were based on prices received by CLUSA-assisted farmer associations in the three regions; November prices were taken from Elanterna; January prices were estimated from Quente-Quente prices reported for nearby regions. Because of low quantities of maize offered for sale in the sample regions no producer prices were available for sample markets in Regions 7, 8 or 10 in this period.

assess potential gains from storage. In each case crop yields were adjusted to reflect storage losses[9] and interest charges according to the length of the loan period. Gross revenue was also adjusted to reflect the opportunity costs associated with selling at different times of the year. Actual maize prices rose throughout 1998, but this will not hold true each year. For example, following a sizable increase in maize area and production in the 1998/99 season, traders offered northern Mozambican farmers 500 mt/kg in September 1999 (Noticias 8/28/99), 50% less than in September 1998. Net income per hectare was also calculated for hypothetical drops in output price of 25% and 50% from the September 1998 values. Two additional scenarios were calculated in which it was assumed that farmers selling in November 1998 or January 1999 were able to decrease their storage losses by half through the use of storage insecticide. Finally, net income was calculated under the assumption that high-input farmers did not repay their input loans.

A review of the budget presented in Table 11 leads to five key conclusions about maize profitability. These are presented below in Sections 4.2 through 4.6.

4.2. Using the Complete High-Input Seed and Fertilizer Package is Financially Risky

Using improved seed and fertilizer at the recommended rates was **less** profitable than using improved or traditional management practices without improved seed and fertilizer, if farmers sold their maize in September shortly after harvest, the most common practice. Net income/ha and per labor day were highest for improved management only groups in all three regions. Returns for high-input and control group maize were positive in Regions 8 and 10, but the use of improved seed and fertilizer technology was risky in Region 7 (Ribaue), where yields were much lower (1.3 tons/ha compared to 2.7 tons/ha in Region 8 and 1.9 tons/ha in Region 10). In Region 7 farmers lost money on high-input maize plots if they sold maize in September.

High-input farmers in both Regions 7 and 10 were vulnerable to losses if September prices dropped by 25%, and high-input farmers in all regions lost money if September prices declined by 50%. Losses ranged from (negative) 185,266 mt in Region 8 to (negative) 759,108 mt in Region 7. Table 12 shows break-even producer prices by technology type and region. Prices range from 60 to 325 mt/kg for improved management only and control group maize, far below the high-input break-even price, which exceeded 500 mt/kg in all regions. High-input prices ranged from 595 mt/kg in Region 8 to 935 mt/kg in Region 10 to 1,110 mt/kg in Region 7.

Median daily wage rates reported by our sample farmers ranged from 12,381 mt/day in Region 7 (Ribaue) to 16,667 mt/day in Regions 8 (Monapo/Meconta) and 10 (Malema). When maize was sold in September, returns to family and mutual labor were generally lower than the median wage rate. The exception was Region 7, where returns per day for improved management only maize were 13,686 mt. If September prices fall by 25%, returns per day are negative in Regions 7 (-6,781 mt)

[9] Maize storage losses were assumed to be 2% per month, the average of various estimates from Abraham et al. 1993.

Table 11: Summary of Results from Farm-Level Maize Enterprise Budgets

	Region 7 -- Ribaue District			Region 8 -- Monapo/Meconta Districts			Region 10 -- Malema District		
	Hi Input	Improved Management Only	Control Group	Hi Input	Improved Management Only	Control Group	Hi Input	Improved Management Only	Control Group
Maize grain yield[a] (tons/ha)	1.3	1.3	1.1	2.7	2.0	1.7	1.9	2.0	1.2
1. September 1998 prices									
September price (mt/kg)	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Net income (mt/ha)	(68,134)	1,272,828	1.030,941	1,204,399	1,660,743	1,434,016	214,509	1,399,380	1,210,142
Net income/labor day (mt/day)	(1,117)	13,686	9,458	16,059	10,315	7,628	4,564	12,957	10,432
2a. November 1998 prices									
November price (mt/kg)	1,714	1,714	1,714	1,520	1,520	1,520	1,714	1,714	1,714
Net income (mt/ha)	667,211	2,010,923	1,637,274	2,204,760	2,400,548	2,090,409	1,245,762	2,488,099	1,906,364
Net income/labor day (mt/day)	10,938	21,623	15,021	29,397	14,910	11,119	26,506	23,038	16,434
2b. November 1998 prices/ storage insecticide used									
Net income (mt/ha)	704,017	2,047,153	1,667,036	2,263,530	2,443,390	2,128,422			
Net income/labor day (mt/day)	11,541	22,012	15,294	30,180	15,176	11,321			
3a. January 1999 prices									
January price (est.) (mt/kg)	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100
Net income (mt/ha)	985,418	2,352,652	1,917,998	3,367,180	3,269,044	2,860,985	1,700,971	2,992,906	2,228,308
Net income/labor day (mt/day)	16,154	25,297	17,596	44,896	20,305	15,218	36,191	27,712	19,210
3b. January 1999 prices/ storage insecticide used									
Net income (mt/ha)	1,087,231	2,452,805	2,001,104	3,573,490	3,417,817	2,993,118	1,843,059	3,139,634	2,323,833
Net income/labor day (mt/day)	17,824	26,374	18,359	47,647	21,229	15,921	39,214	29,071	20,033
4. If credit is not repaid (Sept.)									
Net income (mt/ha)	1,263,566			2,536,099			1,546,209		
Net income/labor day (mt/day)	20,714			33,815			32,898		

Source: Survey data, CLUSA and SIMA reports (for price data) and 10 (5,588 mt), and are negative for all regions if prices drop by 50%, ranging from -2,470 (Region 8), to -12,444 (Region 7) and -15,939 in Region 10.

4.2.1. Region 7 (Ribaue)

In Region 7, net returns per hectare and per labor day were highest for the improved management only group under all price scenarios (Table 11). At September 1998 output prices, high-input farmers **lost** an average of 68,134 mt/ha. Maize yields were not significantly greater than those of low-input maize, and revenue from crop sales was insufficient to cover the costs of improved seed and fertilizer. Net income was positive for the other plot types, 1.3 million mt/ha for the improved management only group, and 1.0 million mt/ha for the control group . Returns per labor day ranged from a loss of 1,117 mt/day for the high-input group to positive returns of 13,686 mt/day for the improved management group and 9,458 mt/day for the control group.

If September producer prices decline by 25% and 50%, losses incurred by high-input farmers are -413,621 and -759,108 mt/ha, respectively. Returns are lower but still positive for the other groups. With a 25% price drop, net income per hectare ranges from 751,568 mt/ha for control plots to 932,744 mt/ha for improved management plots. Returns per day fall below the median daily wage rate for all groups, ranging from losses of 6,781 mt/day (high-input) to gains of 6,895 mt/day for improved management only farmers and 10,030 mt/day for the control group. When prices decline by 50%, returns per hectare fall to 592,659 mt (improved management only) and 472,194 mt (control).

4.2.2. Region 8 (Monapo/Meconta)

At actual September 1998 prices, maize production was profitable for all three technology types in Region 8, but returns were highest for the improved management group (Table 11). Net income per hectare for improved management plots was 1.7 million mt, 38% higher than returns from high-input maize (1.2 million mt) and 16% higher than control plot returns (1.4 million mt). Returns per labor day were lower than median wage rates of 16,667 mt/day for all groups but were greatest for the high-input plots (see Section 4.5. for further discussion). Returns per labor day were 7,628 mt for the control group, 10,315 mt for improved management only plots and 16,059 for high-input farmers.

If producer prices drop by 25%, returns per hectare and per labor day drop but maize production remains profitable for all three technology types. Net income per hectare is 1.2 million mt for improved management plots, 127% greater than high-input returns (509,567 mt) and 17% more than returns from control plots (984,600 mt). High-input farmers will lose 185,266 mt/ha if September producer prices decline by 50%. Returns remain positive for the other groups, 535,185 mt/ha for control plots and 647,693 mt/ha for improved management only farmers.

4.2.3. Region 10 (Malema)

In Region 10 (Malema), net income per hectare from improved management only plots was 1.4 million mt at actual September prices, more than five times greater than returns from high-input plots (214,509 mt/ha) and 16% more than returns for the control group (1.2 million mt/ha) (Table 11). Returns per labor day were below the average daily wage rate of 16,667 mt/day, ranging from 4,564 mt/day (high-input plots) to 12,957 mt/day for improved management only maize.

If prices fall by 25%, high-input farmers lose 267,320 mt/ha, but maize production remains profitable for other groups, 897,743 mt/ha for improved management plots and 889,351 mt/ha for the control group. With a price decline of 50%, high-input losses are -749,150 per hectare, compared to profits of 396,105 mt/ha for improved management plots and 568,561 mt/ha for the control group.

4.3. Gains from Storage

Producer prices rose by 63% between September and November in Regions 7 (Ribaue) and 10 (Malema) and by 45% in Region 8 (Monapo/Meconta). Between September and January prices doubled in all regions. Our analysis suggests that in 1997/98 farmers could have increased net income significantly by holding their maize for sale later in the season, even after accounting for storage losses and additional interest charges.

4.3.1. Gains from Sale in November and January

If farmers stored maize for sale in November, net income/ha for the improved management only group was still higher than returns from other groups across all regions, but in Region 7 high-input farmers achieved profits of 667,211 mt/ha (compared to losses of 68,134 with September sales) (Table 11). Returns to Region 7 improved management and control groups were 58% higher than September returns. In Region 8 (Monapo/Meconta), November returns to high-input maize were 83% higher than in September, and net income/ha from improved management and control plots was 45% higher. Returns from high-input plots in Region 10 were almost 5 times greater in November than September, and returns from improved management and control plots were 58-78% higher in November.

Gains were even higher if farmers waited to sell maize in January (Table 11). When sold at January prices high-input maize became the most profitable group in Region 8 (Monapo/Meconta). In Regions 7 and 10, improved management maize remained more profitable than high-input or control plots. Net income per hectare for Region 7 high-input farmers selling in January was 48% higher than November returns; net income from improved management and control plots was 17% higher than November and 85% higher than September returns. In Region 8, gains from high-input maize sold in January exceeded November returns by 53% and September returns by 180%. Improved management and control group returns were 36% higher than in November and double those of September.

Gains to storage and sales in January were also impressive in Region 10. Returns from high-input plots were 37% and 693% higher than November and September returns respectively. Improved management net income/ha in January was 20% higher than November and 114% higher than September. Control group farmers who sold in January achieved profits that were 17% higher than November and 84% higher than September levels.

4.3.2. Potential Gains from Use of Storage Insecticide

None of the sample farmers used storage insecticide following the 1997/98 production year, but our results indicate that income gains from pesticide use (through reducing the amount of maize lost to storage pests) would be substantial in all regions (Table 11). If farmers used insecticide and storage losses were reduced by half[10], net income per hectare for maize sold in November would increase by a further 2-6% over November net income/ha without storage insecticide, after pesticide costs are deducted. Farmers who used storage insecticide and sold maize in January could increase net incomes by 4-10% over returns when no insecticide is used.

4.4. Improved Seed and Fertilizer Represent 68-80% of Total Production Costs

Improved seed and fertilizer are by far the biggest cost component in the financial enterprise budgets. Purchased seed and fertilizer make up 68-80% of total maize production costs (exclusive of family labor) in the three regions. This suggests that even small reductions in the farmgate cost of fertilizer and seed (e.g., by reducing transport and other marketing costs) could significantly increase farm profits. The input cost reduction does not change the relative ranking of profits for the three technology groups, i.e., in most cases low-input maize is still the most profitable option. However, reducing seed and fertilizer costs by 25% would more than double net income/ha for high-input farmers in Regions 7 and 10 selling in September. Net income/ha for high-input farmers in Region 8 would rise by 28%. If farmers wait until January 1999 to sell, reducing seed and fertilizer costs by 25% results in a 35% increase in net income/ha for Region 7 high-input farmers and 10% and 20% increases for Region 8 and 10 high-input farmers, respectively.

4.5. Labor Use and Management

In earlier sections we discussed the probable yield impact of the delay in input delivery and planting in two of the three regions. In addition to this problem, our analysis of labor data for the three technology types (summarized in Table 13) suggests that farmers participating in the high-input program may have managed these plots less carefully than low-input and non-program plots. Total labor use results are highly variable and must be interpreted with caution since the labor data is based on end-of-season recall. However, in all three zones high-input participants appeared to use substantially fewer labor days/ha -- 39-55% fewer -- than low-input or non-program participants. This result is surprising since it is normally assumed that adoption of high-input technology requires additional labor for planting in rows, fertilizer application and weeding.

We do not have data on the reasons why farmers apparently devoted less labor to the high-input plots. One possibility is that farmers believed that yields had already been significantly compromised by the late input delivery and planting and held back resources as a result. Farmers may also have used improved seed and fertilizer as a substitute for labor -- assuming that they could achieve a target yield (not necessarily the maximum yield) by using the improved inputs

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[10]This is a conservative estimate. Recent research suggests that the application of storage insecticide can reduce storage losses to 2-13% of grain weight over a 5-9 month period (Abraham et al. 1993).

alone -- and transferred labor resources to other crops. As discussed earlier, we also heard anecdotal reports that some farmers used less than the recommended dose of fertilizer on high-input maize and diverted fertilizer to other crops.

Table 14 shows the performance of the high-input package under optimal conditions -- in this case, the results from Region 8's highest yield tercile -- where input delivery and planting were timely and agroecological conditions and crop management were good. Under these conditions yields of high-input maize (4.1 tons/ha) are significantly higher than low-input (2.8 tons/ha) or non-participant plots (2.5 tons/ha). These results should be interpreted with caution because of the small sample size, but the profitability analysis suggests that at these higher yield levels high-input maize is as profitable as improved management only or control group maize if sold in September, and high-input maize is the most profitable of the three groups if maize is sold in November or January. Net income per hectare from high-input plots is 17-23% higher than improved management or control returns in November, and 25-33% higher in January.

4.6. Credit Repayment

It is also possible that farmer expectations about credit repayment had an adverse effect on crop management. In 1996/97 few DNER/SG high-input program participants actually repaid seed and fertilizer credit regardless of their yields (Howard et al. 1998). Given this experience, 1997/98 high-input participants may not have anticipated having to repay the credit either. Informal interviews revealed that very few farmers had repaid credit from the 1997/98 season as of March 1999 or felt that they would be expected to repay credit in the future. As a result farmers may have been less careful about agronomic practices such as timely and adequate weeding of plots that could have increased yields.

If high-input farmers did not expect to repay their loans, our analysis suggests that the reduced management strategy was rational. If credit was **not** repaid, net income/ha for high-input maize was roughly equivalent to low-input earnings in Region 7, and 10-77% higher than net income/ha for low-input and non-participant plots in Regions 8 and 10, when maize was sold in September (Table 11). In all regions, net income per labor day for high-input plots (when credit was not repaid) was much higher -- in most cases twice or three times -- that for low-input and non-program maize, and almost double the median wage rate in each region.

Table 12: Break-even Maize Producer Prices

	Region 7 -- Ribaue District			Region 8 -- Monapo/Meconta Districts			Region 10 -- Malema District		
	Hi-Input Maize	Lo-Input Maize	Non-participant	Hi-Input Maize	Lo-Input Maize	Non-participant	Hi-Input Maize	Lo-Input Maize	Non-participant
Maize grain yield (tons/ha)	1.3	1.3	1.1	2.7	2.0	1.7	1.9	2.0	1.2
Break-even price (mt/kg)	1,100	70	85	595	190	215	935	325	60

Source: Survey data

Table 13: Total Family, Mutual and Wage Labor Days Used in Maize Production

	Region 7 -- Ribaue District			Region 8 -- Monapo/Meconta Districts			Region 10 -- Malema District		
	Hi-Input Maize	Lo-Input Maize	Non-participant	Hi-Input Maize	Lo-Input Maize	Non-participant	Hi-Input Maize	Lo-Input Maize	Non-participant
Total adult-equivalent days	62	93	109	84	171	197	71	142	116

Source: Survey data

Table 14. Results Under Optimal Conditions

	Region 8 -- Monapo/Meconta Districts		
Results from Region 8 Highest Yield Terciles	Hi-Input Maize	Lo-Input Maize	Non-participant
n	11	11	10
Maize grain yield (kg/ha)	4.1	2.8	2.5
1. September 1998 price			
September price (mt/kg)	1,050	1,050	1,050
Net income (mt/ha)	2,583,282	2,479,534	2,400,687
Net income/day (mt)	30,753	15,595	12,064
2. November 1998 price			
November price (mt/kg)	1,520	1,520	1,520
Net income (mt/ha)	4,116,047	3,516,914	3,338,124
Net income/day (mt)	49,001	22,119	16,775
3. January 1999 price			
January price (mt/kg)	2,100	2,100	2,100
Net income (mt/ha)	5,903,484	4,734,749	4,438,630
Net income/day (mt)	70,280	29,778	22,305

4.7. Summary

The analysis in Section 3 suggested that farmers can significantly increase maize yields through the application of the recommended improved seed and fertilizer package, if inputs are delivered on time and crop management recommendations are followed. The results of the financial analysis in Section 4 are more sobering. Under the conditions faced by smallholder farmers in 1997/98 (including uncertainty about weather conditions, the timing of input delivery and commodity prices), the analysis indicates that in most scenarios (sales in September, shortly after harvest, or in November or January) the yield gains did not compensate for the high cost of the inputs, if net income/ha is used as the measure of profitability. Farmers achieved higher returns (net income/ha) when they used only improved management techniques without purchased seed or fertilizer. Only in Region 8 (Monapo/Meconta), where inputs were delivered on time and weather conditions were good, did the profitability of the high-input package exceed that of improved management alone, and then only if farmers waited until January to sell maize (benefitting from a price rise of 100% between September 1997 and January 1998).

We use two measures of profitability in the analysis, net income/ha (discussed above) and net income per day of family labor. The latter can be compared to area wage rates (which approximate the opportunity cost of labor) to assess the relative attractiveness of technology at different yield and price levels. For reasons that are not clear, farmers in the high-input group reported fewer adult-equivalent days of labor than farmers in the other groups, although normally the application of fertilizer and planting seeds in rows is assumed to require more labor. If the labor data are correct, however, use of the high-input package becomes more attractive using the net income/labor day as an indicator of profitability. The high-input package becomes the most profitable (using net income/labor day) alternative in Regions 8 and 10, when maize is held for sale in November or January. More research is required to determine if the labor data provided in the end-of-season recall accurately reflects actual labor inputs by sample farmers.

The results of the financial analysis also suggest that all farmers – regardless of the technology package used – can potentially benefit from gains to storage and later sale of maize, especially when insecticide is used to reduce grain losses to storage pests. Gains from storage are not assured, however. In 1997/98 seasonal price rises were impressive, but in 1998/99 (and into the 2000 marketing season) because of increased production in Mozambique and the southern Africa region generally prices increased very little through the season.

We hypothesize that the lack of clarity regarding whether input credit would have to be repaid, combined with the late delivery of inputs in two of the three regions, may have compromised the technical performance of the improved seed and fertilizer, and reduced farmer incentives to manage their plots – especially weeding – as well as they might have. Even under optimal conditions, however, (the highest yield tercile of Region 8 high-input farmers, who received inputs on time and presumably used good management techniques) net income/ha from the high-input maize package was not significantly different from returns from the other technology groups when maize is sold in September, the most common practice. Profitability (net returns/ha) for high-input maize is significantly higher than the other groups only when farmers hold maize for sale in November and January, and there is a substantial commodity price rise in that period.

The main conclusion that we draw from the financial analysis is that the use of improved technology on maize can be profitable, but the level of risk and uncertainty surrounding use of improved maize technology, and the cost of supplying improved seed and fertilizer, are currently very high. In the final section, we identify the main areas of risk and uncertainty for smallholder farmers and for input suppliers, and discuss possible strategies for reducing risk, uncertainty, and the cost of supplying inputs. We also identify areas where additional research is needed.

5. CONCLUSIONS

Our analysis suggests that there is considerable potential for improved seed and fertilizer technology to increase maize yields in northern Mozambique. However, under the conditions faced by smallholder farmers – including uncertainty about the weather, timing of input delivery, and commodity prices, and the high cost of the inputs themselves – the analysis shows that it is financially risky for smallholders to adopt the full package of seed and fertilizer recommendations (30 kg of improved open-pollinated variety seed, 100 kg 12-24-12, and 100 kg urea per hectare). In 1997/98 the yield increases generated through the use of the technology package generally did not compensate for the high cost of the inputs given the prevailing output prices.

Sample farmers using improved management techniques only (without purchased inputs) achieved higher profits than farmers using either the high-input package or traditional techniques (no purchased inputs) in most regions and scenarios examined (sales in September, November, and January). An exception was Region 8, where good weather conditions and timely input delivery contributed to high maize yields. Even in Region 8, however, net income/ha for high-input users was higher only when farmers stored maize for sale in January, taking advantage of the doubling of maize prices between September 1998 and January 1999. Although significant maize price rises occurred following the 1996/97 and 1997/98 production seasons, farmers cannot rely on them: e.g., maize prices have remained flat following the 1998/99 season due to higher production in southern Africa.

The results of this analysis suggest the need for policy and program actions, and further research, to reduce (1) the risks and uncertainty of input use at the farm level, and (2) the cost of input supply, to allow Mozambican smallholders to benefit from technological improvements that can potentially increase yields, food security and incomes. Potential actions and research include:

Reducing production risk by fine-tuning agronomic recommendations. There were significant differences in yield response between the three agroecological regions studied. Because a large part of the differences may be attributable to variations in altitude, rainfall, and soils, this suggests the need for fine-tuning the blanket country-wide agronomic recommendations. Some researchers have already begun to modify recommendations (Estacao Agraria and Extensao Rural/Nampula 1999; Penninkhoff, Augusto and Anman 1999), but a much more aggressive approach is needed, including high-level support from national and provincial research and extension directors. Institutional incentives are required to motivate researchers and extensionists to modify technology recommendations for specific areas by synthesizing the results from on-station and on-farm trials, including INIA's national geographically-referenced database on soil quality and response to fertilizer.

Focusing more adaptive research and extension effort on solving problems that seriously affect maize yield. Our analysis indicates that plant density -- in conjunction with improved seed and fertilizer use-- is the most important determinant of maize yield. Our results revealed very high levels of variation in plant density among high-input farmers. The recommended plant density level was 50,000 plants per hectare, yet our high-input farmers registered densities of 26,000-33,000 plants per hectare. Closer extension supervision at planting time may be required, but adaptive research is also needed to help solve other problems identified by farmers. For example, many farmers reported that termite attacks significantly reduced plant population. Other problems noted were related to weather and seed supply. Many farmers reported that they lost seedlings because of an unexpected break in rains occurring soon after emergence. When farmers plant local seed they can easily replant these areas, but improved seed supplies are usually very limited. After farmers plant a field once, it is difficult to find replacement seed locally or, in the case of 1997/98, even at the provincial level. Our region-specific data indicate that farmer-reported drought had a significant impact on yields in Regions 7 and 10, which had poorer maize yields. This result suggest a need for better agronomic and supply strategies to deal with drought – perhaps different planting times (these were areas where farmer received and planted improved seed late), or shorter-season varieties that can be planted later after the main rains have begun.

Adjusting agronomic recommendations according to farmers' ability to bear risk. Recommendations, particularly for expensive inputs such as commercial fertilizer, may also need to be adjusted on the basis of farmers' capacity to bear risk. For example, farmers who have more than one commercial crop, e.g., cotton and maize, may have a higher risk threshold. In the event of a poor return on one crop (maize), maize input loans can be paid off with returns from cotton. More research needs to be carried out to understand how farmers perceive risks and the attractiveness of alternative investments within the farming system, but preliminary results suggest the need for recommendations geared not only to agroecological differences but to variations in farmers' ability to spread risk among different crops in the farming system or among different on- and off-farm enterprises.

Improving research and extension on the costs, returns and risks of alternative technologies in a cropping systems context. Through the efforts of the Cooperative League of the USA (CLUSA) and other NGOs, farmers in Nampula Province are becoming more aware of the potential costs and returns from alternative commercial crops, e.g., cotton, maize, sunflower, sesame, pigeon pea-- and the importance of analyzing these during pre-season planning. Researchers and extensionists can contribute significantly to this discussion, by (1) collecting data on labor inputs and carrying out financial analysis of trials (especially on-farm trials) of new technology and crop management techniques; (2) making information on yield and profitability available to farmers in an easy-to-understand extension bulletin format; (3) DNER, DAP and SIMA (Market Information System) collaboration to assess and extend information about the price risk associated with alternative commodities; and (4) improving research and extension on alternative crops and technologies in a cropping systems context. For example, cropping systems-based research can help answer questions such as (a) what rotations should be planned to maintain soil fertility? (b) what combinations of commercial and subsistence crops, and technologies, should be considered in specific agroecological zones to meet the objectives and risk-carrying capacity of different types of farmers?

Reducing the cost of input supply. Our analysis showed that the cost of improved seed and fertilizer represented 68-80% of production costs (exclusive of family labor) for sample farmers. Reducing costs at strategic points in the input sector will clearly improve the farm-level profitability of improved technology. The research activity described in this paper did not focus on the impact of government and donor policies and programs on input supply, but these are discussed at length in a recent DAP study on constraints and strategies for the development of the Mozambican inputs sector (2000). Key recommendations include (a) investments to reduce transport costs, including road, rail and shipping infrastructure, and incentives to the private sector to expand and maintain rural transport fleets; (b) government withdrawal from management of the KRII program for supply of fertilizer, pesticides and machinery; (c) reduction of policy barriers to the regional trade in inputs by the private sector, and research to explore the possibility of reducing shipping and transport costs through bulk ordering of fertilizer with partners in neighboring countries; (d) expansion of programs to train input dealers in rural areas; and (e) programs to supply improved seed varieties to remote, less commercially developed areas of Mozambique.

Farmer associations are increasingly active in Nampula Province and present one of the most promising avenues for lowering input and output marketing costs. Farmer associations can potentially lower the private sector costs of input supply and credit recovery, and increase extension effectiveness, by (a) aggregating input demand from scattered rural villages; (b) organizing local delivery of inputs to member villages after inputs are delivered by the supplier to a central location; (c) providing group guarantees for input loans; and (d) organizing extension assistance on a group basis. During the 1998/99 season, for the first time, 21 farmer associations participated in the DNER/SG intensive maize program. Research is underway to assess the impact of these farmer associations on program implementation, and on input and output marketing costs. Preliminary results will be reported in early 2000.

APPENDIX 1: YIELD DETERMINANTS MODELS

Table 15. Regression Analysis of Factors Affecting Plant Density -- Regions 7,8,10

	All Zones (Adj. R^2=.34, F=11.538)[a]				
Variables	Coef.	SE Coef.	Stdized Coeff.	T	Sig. T
Constant	9.506	.153		62.000	.000
TECH1 1=fertilizer, improved seed 0=otherwise	.680	.079	.676	8.568	.000
TECH2 1=improved practices 0=otherwise	.116	.076	.112	1.512	.132
REGION 8 1=Region 8 0=otherwise	.108	.069	.109	1.559	.121
PLTLAHA number of adult-equivalent labor days used for planting	-.0043	.003	.090	1.422	.157
OTHERDAM 1=reported significant damage from termites, wind,drought,flood,or rats 0=no or little damage	-.061	.066	-.058	-.918	.360
SOILFERT 1=high or medium fertility 0=low	.0756	.113	.042	.666	.506
WKPLANT week of planting; 1=4th week October 2=1st week November etc.	-.0055	.012	-.030	-.457	.648
EDUC grade level completed	-.0043	.013	-.021	-.324	.746
REGION 10 1=Region 10 0=otherwise	-.00566	.092	-.004	-.062	.951

Source: Survey data

Table 16. Regression Analysis of Factors Affecting Plant Density -- Region 7

	Region 7 (Adj. R^2=.48, F=10.85)				
Variables	Coef.	SE Coef.	Stdized Coeff.	T	Sig. T
Constant	9.596	.161		59.641	.000
TECH1 1=fertilizer, improved seed 0=otherwise	.834	.109	.805	7.649	.000
TERMITE 1=reported significant damage from termites 0=no or little damage	-.189	.137	-.143	-1.381	.172
TECH2 1=improved practices 0=otherwise	.155	.116	.141	1.334	.187
DROUGHT 1=reported significant damage from drought 0=no or little damage	-.142	.133	-.105	-1.060	.293
PLTLAHA number of adult-equivalent labor days used for planting	-.0073	.006	-.104	-1.180	.242
EDUC grade level completed	-.0151	.022	-.061	-.689	.493
SOILFERT 1=high or medium fertility 0=low	.0233	.137	.015	.170	.866

Source: Survey data

Table 17. Regression Analysis of Factors Affecting Plant Density -- Region 8

	Region 8(Adj. R^2=.34, F=7.98)				
Variables	Coef.	SE Coef.	Stdized Coeff.	T	Sig. T
Constant	9.227	.213		43.296	.000
TECH1 1=fertilizer, improved seed 0=otherwise	.623	.110	.629	5.642	.000
SOILFERT 1=high or medium fertility 0=low	.507	.201	.229	2.528	.014
RAINGD 1=reported good rainfall distribution in current season 0=average or poor rainfall distribution	.159	.127	.118	1.254	.214
TECH2 1=improved practices 0=otherwise	.043	.105	.044	.410	.683
EDUC grade level completed	-.0027	.019	-.013	-.138	.890
TERMITE 1=reported significant damage from termites 0=no or little damage	.0028	.113	.002	.025	.980

Source: Calculated from MAP/MSU survey data

Table 18. Regression Analysis of Factors Affecting Plant Density -- Region 10

	Region 10(Adj. R^2=.2, F=2.45)				
Variables	Coef.	SE Coef.	Stdized Coeff.	T	Sig. T
Constant	9.902	.231		42.872	.000
TECH1 1=fertilizer+improved seed 0=otherwise	.641	.228	.667	2.807	.010
RAINBAD 1=farmer reported poor rainfall distribution in current season 0=average or good rainfall distribution	-.338	.188	-.314	-1.795	.085
REDSOIL 1=if soil is red in color 0=otherwise	-.239	.170	-.246	-1.403	.173
TECH2 1=improved practice/extension assistance 0=otherwise	.203	.217	.201	.934	.360
OTHERDAM 1=reported significant damage from termites, wind, drought, flood, or rats 0=no or little damage	-.086	.180	-.085	-.476	.639

Source: Survey data

APPENDIX 2: FARM-LEVEL FINANCIAL BUDGETS

Table 19. Summary of Farm Level Enterprise Budget for Region 7 (Ribaue), by Technology Type

Plot Type/ Budget Item	(A) Hi-Input				(B) Improved Management Only				(C) Control Group			
(terciles)	1	2	3	mean	1	2	3	mean	1	2	3	mean
n used in calculations	11	12	11	34	9	9	9	27	7	7	7	21
1. GRAIN YIELD (kg/ha) [1]	626	1,268	2,140	1,343	781	1,152	2,035	1,322	698	1,041	1,517	1,086
1. A. Sept. 1998 adjusted yield (kg/ha) [2]	614	1,243	2,097	1,316	765	1,129	1,994	1,296	684	1,020	1,487	1,064
1.B. Nov. 1998 adjusted yield	589	1,193	2,014	1,264	735	1,084	1,915	1,244	657	980	1,428	1,022
1.C. Nov. 1998 adj. yield if storage losses decline by 50%	607	1,230	2,076	1,303	758	1,118	1,975	1,283	677	1,010	1,472	1,054
1.D. Jan. 1999 adjusted yield	566	1,146	1,934	1,214	706	1,041	1,839	1,195	631	941	1,371	982
1.E. Jan. 1999 adj. yield if storage losses decline by 50%	595	1,206	2,035	1,277	743	1,096	1,935	1,257	664	990	1,443	1,033
2. EST. FARMGATE PRICE [3]												
2.A. Sept. 1998	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
2.B. Nov. 1998	1,714	1,714	1,714	1,714	1,714	1,714	1,714	1,714	1,714	1,714	1,714	1,714
2.C. Jan. 1999	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100
3. GROSS REVENUE[4]												
3.A. Sept. 1998 sale	644,154	1,304,772	2,202,060	1,381,947	803,649	1,185,408	2,094,015	1,360,338	718,242	1,071,189	1,560,993	1,117,494
3.B. Nov. 1998 sale	993,354	2,012,718	3,396,859	2,131,767	1,239,695	1,828,590	3,230,191	2,098,433	1,107,947	1,652,397	2,407,960	1,723,827
3.C. Nov. 1998 sale if storage losses decline by 50%	1,024,726	2,075,643	3,503,057	2,198,414	1,278,452	1,885,758	3,331,178	2,164,038	1,142,586	1,704,057	2,483,242	1,777,720
3.D. Jan. 1999 sale	1,155,809	2,340,488	3,950,035	2,478,924	1,441,578	2,126,374	3,756,225	2,440,162	1,288,376	1,921,489	2,800,095	2,004,551
3.E. Jan. 1999 sale if storage losses decline by 50%	1,216,349	2,465,450	4,160,171	2,610,578	1,518,940	2,240,593	3,955,731	2,569,690	1,357,436	2,023,871	2,949,963	2,111,788
4. TOTAL PACKAGE COSTS [5]	**1,158,000**	**1,158,000**	**1,158,000**	**1,158,000**	**23,122**	**37,130**	**15,800**	**23,700**	**26,070**	**14,220**	**45,030**	**16,590**
4.A. Seed (mt/ha)	198,000	198,000	198,000	198,000	23,122	37,130	15,800	23,700	26,070	14,220	45,030	16,590
4.B. 12-24-12 and Urea Fertilizers	960,000	960,000	960,000	960,000	0	0	0	0	0	0	0	0
5. INTEREST [6]												
5.A. Sept. 1998	173,700	173,700	173,700	173,700	0	0	0	0	0	0	0	0
5.B. Nov. 1998	188,175	188,175	188,175	188,175								
5.C. Jan. 1999	217,125	217,125	217,125	217,125								
6. LABOR												
6.A. Total family/mutual labor (days/ha) [7]	41	73	67	61	94	94	79	93	139	61	123	109
6.B. Total wage labor (mt/ha) [8]	158,546	14,185	93,955	86,698	39,272	21,343	0	20,205	2,143	28,571	0	10,238
7. HAND TOOLS AND SACKS (mt/ha)	**29,437**	**30,762**	**38,020**	**31,683**	**48,919**	**48,704**	**45,050**	**43,605**	**46,667**	**47,990**	**90,161**	**59,725**

7.A. Hand tools (mt/ha)[9]	20,716	18,972	18,459	19,313	33,406	29,549	22,410	26,250	35,000	29,149	52,500	38,313
7.B. Sacks (mt/ha)[10]	8,721	11,790	19,561	12,370	15,513	19,155	22,640	17,355	11,667	18,841	37,661	21,412
8. NET INCOME/HA [11]												
8.A. Sept. 1998 sale	(875,529)	(71,875)	738,385	(68,134)	692,336	1,078,231	2,033,165	1,272,828	643,362	980,408	1,425,802	1,030,941
8.B. Nov. 1998 sale	(540,804)	621,596	1,918,709	667,211	1,128,382	1,721,413	3,169,341	2,010,923	1,033,067	1,561,616	2,272,769	1,637,274
8.C. Nov. 1998 sale if storage losses decline by 50%	(523,342)	656,346	1,977,356	704,017	1,149,785	1,752,984	3,225,110	2,047,153	1,052,196	1,590,145	2,314,343	1,667,036
8.D. Jan. 1999 sale	(407,299)	920,416	2,442,935	985,418	1,330,265	2,019,197	3,695,375	2,352,652	1,213,496	1,830,708	2,664,904	1,917,998
8.E. Jan. 1999 sale if storage losses decline by 50%	(360,669)	1,017,203	2,605,520	1,087,231	1,390,273	2,107,819	3,849,663	2,452,805	1,267,046	1,909,959	2,781,064	2,001,104
9. NET INCOME/FAMILY-MUTUAL LABOR DAY[12]												
9.A. Sept. 1998 sale	(21,354)	(985)	11,021	(1,117)	7,365	11,471	25,736	13,686	4,629	16,072	11,592	9,458
9.B. Nov. 1998 sale	(13,190)	8,515	28,637	10,938	12,004	18,313	40,118	21,623	7,432	25,600	18,478	15,021
9.C. Nov. 1998 sale if storage losses decline by 50%	(12,764)	8,991	29,513	11,541	12,232	18,649	40,824	22,012	7,570	26,068	18,816	15,294
9.D. Jan. 1999 sale	(9,934)	12,608	36,462	16,154	14,152	21,481	46,777	25,297	8,730	30,012	21,666	17,596
9.E. Jan. 1999 sale if storage losses decline by 50%	(8,797)	13,934	38,888	17,824	14,790	22,424	48,730	26,374	9,115	31,311	22,610	18,359
10. NET INCOME/HA IF HIGH- INPUT CREDIT NOT REPAID SEPT. 1998	456,171	1,259,825	2,070,085	1,263,566								
11. NET INCOME/LABOR DAY IF HIGH-INPUT CREDIT NOT REPAID SEPT. 1998	11,126	17,258	30,897	20,714								
Median Wage [13]	12,381	12,381	12,381	12,381	12,381	12,381	12,381	12,381	12,381	12,381	12,381	12,381
Total labor (days/ha)[14]	60	73	67	65	98	100	79	94	139	61	123	110

Table 20. Summary of Farm Level Enterprise Budget for Region 8 (Monapo/Meconta), by Technology Type

Plot type/ Budget Item	(A) Hi-Input				(B) Improved Management Only				(C) Control Group			
(terciles)	1	2	3	mean	1	2	3	mean	1	2	3	mean
n used in calculations	10	11	11	32	11	12	11	34	10	10	10	30
1. GRAIN YIELD (kg/ha) [1]	1,328	2,533	4,118	2,701	1,200	1,946	2,761	1,969	1,009	1,736	2,495	1,747
1.A. Sept. 1998 adjusted yield[2]	1,301	2,482	4,036	2,647	1,176	1,907	2,706	1,930	989	1,701	2,445	1,712
1.B. Nov. 1998 adjusted yield	1,250	2,384	3,876	2,542	1,129	1,832	2,599	1,853	950	1,634	2,348	1,644
1.C. Nov. 1998 adj. yield if storage losses decline by 50%	1,289	2,458	3,996	2,621	1,164	1,888	2,679	1,911	979	1,684	2,421	1,695
1.D. Jan. 1999 adjusted yield	1,200	2,290	3,722	2,441	1,085	1,759	2,496	1,780	912	1,569	2,255	1,579
1.E. Jan. 1999 adj. yield if storage losses decline by 50%	1,263	2,409	3,916	2,569	1,141	1,851	2,626	1,872	960	1,651	2,373	1,661
2. EST. FARMGATE PRICE (mt/kg) [3]												
2.A. Sept. 1998	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
2.B. Nov. 1998	1,520	1,520	1,520	1,520	1,520	1,520	1,520	1,520	1,520	1,520	1,520	1,520
2.C. Jan. 1999	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100
3. GROSS REVENUE [4]												
3.A. Sept. 1998 sale	1,366,512	2,606,457	4,237,422	2,779,329	1,234,800	2,002,434	2,841,069	2,026,101	1,038,261	1,786,344	2,567,355	1,797,663
3.B. Nov. 1998 sale	1,923,880	3,669,569	5,965,765	3,912,951	1,738,445	2,819,179	3,999,873	2,852,499	1,461,743	2,514,951	3,614,518	2,530,887
3.C. Nov. 1998 sale if storage losses decline by 50%	1,865,476	3,558,171	5,784,662	3,794,165	1,685,671	2,733,597	3,878,449	2,765,906	1,417,369	2,438,604	3,504,792	2,454,056
3.D. Jan. 1999 sale	2,451,237	4,675,439	7,601,049	4,985,535	2,214,973	3,591,948	5,096,284	3,634,402	1,862,423	3,204,328	4,605,298	3,224,632
3.E. Jan. 1999 sale if storage losses decline by 50%	2,581,972	4,924,758	8,005,520	5,251,861	2,332,551	3,784,044	5,368,384	3,826,926	1,962,566	3,375,165	4,851,171	3,395,583
4. TOTAL PACKAGE COSTS [5]	1,158,000	1,158,000	1,158,000	1,158,000	59,455	54,050	32,430	54,050	108,100	54,050	27,025	54,050
4.A. Seed (mt/ha)	198,000	198,000	198,000	198,000	59,455	54,050	32,430	54,050	108,100	54,050	27,025	54,050
4.B. 12-24-12 and Urea Fertilizers	960,000	960,000	960,000	960,000	0	0	0	0	0	0	0	0
5. INTEREST[6]												
5.A. Sept. 1998	173,700	173,700	173,700	173,700	0	0	0	0	0	0	0	0
5.B. November 1998	188,175	188,175	188,175	188,175	0	0	0	0	0	0	0	0
5.C. January 1999	217,125	217,125	217,125	217,125	0	0	0	0	0	0	0	0
6. LABOR												
6.A.Total family/mutual labor (days/ha) [7]	61	97	84	75	145	188	159	161	213	176	199	188
6.B. Total wage labor (mt/ha) [8]	237,111	58,600	264,182	187,533	188,455	343,056	293,091	276,873	427,650	287,333	98,810	271,264
7. HAND TOOLS AND SACKS (mt/ha)	**44,103**	**71,250**	**58,258**	**55,697**	**34,000**	**40,247**	**36,014**	**34,435**	**35,232**	**41,925**	**40,833**	**38,333**
7.A. Hand tools (mt/ha) [9]	22,885	30,000	19,091	23,333	21,000	19,789	13,076	17,213	24,243	21,875	17,500	21,000

7.B. Sacks (mt/ha) [10]	21,218	41,250	39,167	32,364	13,000	20,458	22,938	17,222	10,989	20,050	23,333	17,333
8. NET INCOME/HA [11]												
8.A. Sept. 1998 sale	(246,402)	1,144,907	2,583,282	1,204,399	952,890	1,565,081	2,479,534	1,660,743	467,279	1,403,036	2,400,687	1,434,016
8.B. Nov. 1998 sale	238,087	2,082,146	4,116,047	2,204,760	1,403,761	2,296,244	3,516,914	2,400,548	846,387	2,055,296	3,338,124	2,090,409
8.C. Nov. 1998 sale if storage losses decline by 50%	266,983	2,137,261	4,205,648	2,263,530	1,429,871	2,338,586	3,576,989	2,443,390	868,341	2,093,069	3,392,411	2,128,422
8.D. Jan. 1999 sale	794,898	3,170,464	5,903,484	3,367,180	1,933,063	3,154,595	4,734,749	3,269,044	1,291,441	2,821,020	4,438,630	2,860,985
8.E. Jan. 1999 sale if storage losses decline by 50%	896,125	3,363,500	6,216,453	3,573,490	2,023,977	3,303,451	4,945,500	3,417,817	1,369,164	2,953,283	4,629,064	2,993,118
9. NET INCOME/FAMILY-MUTUAL LABOR DAY [12]												
9.A. Sept. 1998 sale	(4,039)	11,803	30,753	16,059	6,572	8,325	15,595	10,315	2,194	7,972	12,064	7,628
9.B. Nov. 1998 sale	**3,903**	**21,465**	**49,001**	**29,397**	**9,681**	**12,214**	**22,119**	**14,910**	**3,974**	**11,678**	**16,775**	**11,119**
9.C. Nov. 1998 sale if storage losses decline by 50%	**4,377**	**22,034**	**50,067**	**30,180**	**9,861**	**12,439**	**22,497**	**15,176**	**4,077**	**11,892**	**17,047**	**11,321**
9.D. Jan. 1999 sale	**13,031**	**32,685**	**70,280**	**44,896**	**13,332**	**16,780**	**29,778**	**20,305**	**6,063**	**16,029**	**22,305**	**15,218**
9.E. Jan. 1999 sale if storage losses decline by 50%	**14,691**	**34,675**	**74,005**	**47,647**	**13,959**	**17,572**	**31,104**	**21,229**	**6,428**	**16,780**	**23,262**	**15,921**
10. NET INCOME/HA IF HIGH-INPUT CREDIT NOT REPAID SEPT. 1998	**1,085,298**	**2,476,607**	**3,914,982**	**2,536,099**								
11. NET INCOME/LABOR DAY IF HIGH-INPUT CREDIT NOT REPAID SEPT. 1998	**17,792**	**25,532**	**46,607**	**33,815**								
Median Wage [13]	16,667	16,667	16,667	16,667	16,667	16,667	16,667	16,667	16,667	16,667	16,667	16,667
Total labor (days/ha)[14]	71	111	84	89	145	192	159	161	241	180	199	213

Table 21. Summary of Farm Level Enterprise Budget for Region 10 (Malema), by Technology Type

Plot type/ Budget Item	(A) Hi Input	(B) Improved Management Only	(C) Control Group
	mean	mean	mean
n used in calculations	13	10	7
1. GRAIN YIELD (kg/ha) [1]	1,873	1,950	1,247
1.A. Sept. 1998 adjusted yield	1,836	1,911	1,222
1.B. Nov. 1998 adjusted yield	1,763	1,835	1,174
1.C. Nov. 1998 adj. yield if storage losses decline by 50%	1,817	1,892	1,210
1.D. Jan. 1999 adjusted yield	1,693	1,763	1,127
1.E. Jan. 1999 adj. yield if storage losses decline by 50%	1,781	1,854	1,186
2. EST. FARMGATE PRICE (mt/kg) [3]			
2.A. Sept. 1998	1,050	1,050	1,050
2.B. Nov. 1998	1,714	1,714	1,714
2.C. Jan. 1999	2,100	2,100	2,100
3. GROSS REVENUE [4]			
3.A. Sept. 1998 sale	1,927,317	2,006,550	1,283,163
3.B. Nov. 1998 sale	2,973,045	3,095,269	1,979,385
3.C. Nov. 1998 sale if storage losses decline by 50%	3,065,993	3,192,038	2,041,267
3.D. Jan. 1999 sale	**3,457,204**	**3,600,076**	**2,301,329**
3.E. Jan. 1999 sale if storage losses decline by 50%	**3,640,910**	**3,790,133**	**2,424,562**
4. TOTAL PACKAGE COSTS [5]	**1,158,000**	**37,920**	**17,380**
4.A. Seed (mt/ha)	198,000	37,920	17,380
4.B. 12-24-12 and Urea Fertilizers	960,000	0	0
5. INTEREST[6]			
5.A. Sept. 1998 [6]	173,700	0	0
5.B. Nov. 1998	188,175	0	0
5.C. Jan. 1999	217,125	0	0
6. LABOR			
6.A. Total family/mutual labor (days/ha) [7]	47	108	116
6.B. Total wage labor (mt/ha) [8]	333,153	516,667	0
7. HAND TOOLS AND SACKS (mt/ha)	**47,955**	**52,583**	**55,641**
7.A. Hand tools (mt/ha) [9]	25,455	33,015	32,308
7.B. Sacks (mt/ha) [10]	22,500	19,568	23,333

8. NET INCOME/HA [11]			
8.A. Sept. 1998 sale	214,509	1,399,380	1,210,142
8.B. Nov. 1998 sale	**1,245,762**	**2,488,099**	**1,906,364**
8.C. Nov. 1998 sale if storage losses decline by 50%	**1,297,092**	**2,541,539**	**1,940,538**
8.D. Jan. 1999 sale	**1,700,971**	**2,992,906**	**2,228,308**
8.E. Jan. 1999 sale if storage losses decline by 50%	**1,843,059**	**3,139,634**	**2,323,833**
9. NET INCOME/FAMILY-MUTUAL LABOR DAY [12]			
9.A. Sept. 1998 sale	4,564	12,957	10,432
9.B. Nov. 1998 sale	26,506	23,038	16,434
9.C. Nov. 1998 sale if storage losses decline by 50%	27,598	23,533	16,729
9.D. Jan. 1999 sale	36,191	27,712	19,210
9.E. Jan. 1999 sale if storage losses decline by 50%	39,214	29,071	20,033
10. NET INCOME/HA IF HIGH-INPUT CREDIT NOT REPAID SEPT. 1998	**1,546,209**		
11. NET INCOME/LABOR DAY IF HIGH-INPUT CREDIT NOT REPAID SEPT. 1998	**32,898**		
Median Wage [13]	16,667	16,667	16,667
Total labor (days/ha)[14]	70	168	116

Notes for Tables 19-21:

[1] Source: crop cut estimates from DNER/DEA/MSU Survey. Yield at harvest. Assumes no grain is lost during shelling.
[2] Assumes maize is harvested in mid-late July and sold in September, with storage losses of 2% per month.
[3] Prices received by farmers in CLUSA-assisted associations in September 1998. November 1998 and January 1999 based on SIMA reports.
[4] Adjusted grain yield * price.
[5] DNER/SG Inputs Program Participants receive inputs for a half-hectare plot. Per-hectare rates are 30 kg SEMOC-1 seed, 100 kg each 12-24-12 and urea. Seed for low-input and non-program participants valued at grain prices prevailing during the planting month.
[6]DNER/SG Inputs Program interest rate is 22.5% per year(12-month period).
[7]Median adult equivalent days per hectare of family + mutual labor from survey data. Includes harvest but not processing labor. Family labor is unpaid labor by members of the household. Mutual labor is unpaid labor from outside the household which is either unpaid -- either in cash or in kind -- or where laborer is paid only with a meal or drink.
[8]Median values of cash and in-kind payments for labor (excluding meals and drinks) reported by survey participants.
[9]Depreciated value of 2 hoes, 2 large and 2 small machetes, 2 knives, 2 sharpening files. Depreciated value of tool package was apportioned according to percentage of total cultivated area represented by target maize plot. Purchase prices based on reports by survey supervisors.
[10]Number of sacks needed was calculated based on the assumption that the farmer would market the entire 1997/98 production. Since sacks are used for other farm activities, cost was apportioned according to percentage of total cultivated area represented by target maize plot. Each “90 kg size sack” holds 85 kg of maize grain. Purchase price of sacks based on reports by survey supervisors.
[11](3) - (4 +5 +6.B.+7)
[12](8)/(6.A).
[13] From survey data.
[14] Median adult equivalent days of family + mutual labor plus mean days of wage labor per hectare from survey data.

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